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Incremental user charges or prices as a means of assuring equity and efficiency in solid waste management have interested economists for some time. The ultimate effects of pricing are not well-known, however, and most communities continue to rely on revenues from property taxes and flat charges to finance the collection and disposal of residential solid waste. The Symposium sponsored by the Municipal Environmental Research Laboratory (Cincinnati, Ohio) provided an opportunity for economists interested in solid waste problems to exchange ideas and views on the potential role of pricing in municipal solid waste management. This report contains the formal papers presented at the Symposium held at Philadelphia, Pennsylvania on September 19 and 20, 1978.

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PROCEEDINGS OF A SYMPOSIUM ON ECONOMIC APPROACHES TO SOLID WASTE MANAGEMENT

by

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

On September 19 and 20, 1978, a group of economists interested in finding solutions to the solid waste problem met at Philadelphia, Pennsylvania. The express purpose of the meeting was to exchange ideas and views on the potential role of pricing in municipal solid waste management. This report contains the formal papers given at that Symposium.

Francis T. Mayo
Director
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Research Laboratory

ABSTRACT

This report contains the papers presented at a Symposium on Economic Approaches to Solid Waste Management at Philadelphia, Pennsylvania, on September 19 and 20, 1978. The symposium was sponsored by the Municipal Environmental Research Laboratory of the U.S. Environmental Protection Agency. Its purpose was to review the state of the art in user charges and product charges for non-hazardous municipal solid waste, and to provide a forum for researchers to exchange their views on methods and results in the field.

To aid in its assessment of the state of the art, the symposium participants considered four key questions:

1. Do incentive systems designed to alter waste generation behavior actually improve the economic efficiency of solid waste management and/or the equity of its financing?
2. What is the optimal combination of incentive mechanisms? For example, would the best system include some mix of a user charge and a product charge?
3. How do incentives relate to the choice of resource recovery technology?
4. What are the best ways to pursue the testing of the effects of incentive mechanisms? Should we use historical data? Should we try to conduct experiments?

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SECTION 1

INTRODUCTION AND SUMMARY

"Introduction and Summary" (Robert J. Anderson, Jr.).

"Can Economic Incentives Help Resolve Solid Waste Management Problems? (Haynes C. Goddard).

INTRODUCTION AND SUMMARY

by

ROBERT J. ANDERSON, JR.

INTRODUCTION

In late spring of 1978, Oscar Albrecht and Haynes Goddard of the Municipal Environental Research Laboratory, U. S. Environmental Protection Agency began to make tentative plans for a workshop on the role of pricing in municipal solid waste management. Albrecht and Goddard, both of whom are resource economists actively studying pricing policies for residential solid waste management, felt that the pace of research on the subject had so quickened over the last few years that the time was ripe for researchers working in the area to come together. The objectives of so doing were to define the current state of knowledge concerning the role of pricing policies in solid waste management and to identify research needs for the coming years.

To host the workshop, EPA contracted with the JACA Corporation which subcontracted with MATHTECH to organize the workshop sessions and to prepare the workshop report. The workshop was organized into five sessions at which prepared papers were delivered and discussed. The agenda for the workshop is contained in an appendix to this volume.

The workshop tasks, as noted above, were i) to identify the current state of knowledge concerning the role of pricing in solid waste management, and ii) to identify research needs in this area. In an effort to accomplish this, these tasks were narrowed in two important ways. First, the workshop considered only non-hazardous wastes. Economists generally are in agreement that there is little or no role for pricing policies in management of wastes which, if mismanaged, can result in catastrophy.

Second, the workshop participants organized their papers and discussions around two of the most widely-discussed and intensely-researched classes of pricing policies, "user charges" and "product charges". The difference between these two approaches lies in the point at which the price is levied. Under the product charge, the price is levied directly upon producers of goods which, when consumed, generate solid wastes. Under the user charge, the price is levied directly upon consumers as they dispose their wastes.

It was clear from the outset of the workshop that Albrecht and Goddard were right about the need for researchers to meet. The workshop discussions were pointed -- at some times heated -- and researchers clearly needed the opportunity afforded by this workshop to exchange ideas and argue out points of difference. Indeed, several of the discussions begun at the workshop have continued afterward.

This report contains the papers and a summary of the discussions that took place at the workshop. Even a casual examination of its contents will show that a great deal of progress has been made in understanding the effects of pricing policies on the cost and effectiveness of solid waste management. In particular, the papers and discussions in the pages to follow contain evidence that pricing policies can improve the cost and effectiveness of solid waste management, although the gains over present policies that do not incorporate pricing approaches seem to be relatively small given today's economics. Tomorrow, however, the story may be quite different. If landfill costs and the prices of virgin materials exhibit the marked relative increases which many observers forecast, pricing policies could result in a substantial improvement in the efficiency of solid waste management.

The following pages will also show that our knowledge is relatively weak on what might be called the "political economy" of pricing approaches to solid waste management. Workshop participants were unanimous in their call for expanded effort in the study of administrative, political, and legal factors bearing upon the workability of pricing approaches.

SUMMARY OF PAPERS

Charge to the Workshop

The charge to the workshop was delivered in an opening address by Haynes Goddard. Pointing out that economic approaches to solid waste management have failed for the most part to grasp the attention of those responsible for making and implementing policy, Goddard laid much of the blame squarely on economists. Our faults, Goddard noted, are an excessive preoccupation with theory as opposed to practice, and a failure to deal effectively and convincingly with difficult (but solvable) empirical problems in our applied work.

As a point of departure for correcting these faults, Goddard recommended that the economics profession take stock of current and needed knowledge. To this end, Goddard asked workshop participants to consider four key questions:

1. Do incentive systems designed to alter waste generation behavior actually improve the economic efficiency of solid waste management and/or the equity of its financing?

2. What is the optimal combination of incentive mechanisms? For example, would the best system include some mix of a user charge and a product charge?

3. How do incentives relate to the choice of resource recovery technology?

4. What are the best ways to pursue the testing of the effects of incentive mechanisms? Should we use historical data? Should we try to conduct experiments?

As will become clear below, the papers presented at the workshop and the discussions that surrounded them all related to one or more of these questions. Accordingly, I have chosen to organize my summary of the papers presented and workshop discussions by the questions to which they pertain.

Pricing and the Efficiency of Solid Waste Management

Four of the papers presented pertained directly to the question raised by Goddard concerning the effects of incentives of the efficiency of solid waste management. These papers included those by William Lanen, Steve Buchanan, W. David Conn, and Barbara Stevens.

In a paper on the effect of user charges on the efficiency of solid waste management, Lanen presented the results of case studies of user charges in five municipalities. In general, Lanen's results showed no statistically significant effect of user charges on the quantity of waste presented for collection, the usage of special services, or the degree of littering. He did not examine the effect of user charges on costs of collection or administration of solid solid waste systems.

Lanen cautioned that his failure to find significant relationships between user charges and household solid waste behavior does not mean that there is no relationship. Rather, he concluded that, due to data and specificaton problems, the historical case study approach is not particularly well-suited to measuring any relationships which may exist. His results thus leave open the question concerning the effect of user charges on solid waste management efficiency.

Buchanan's paper focused on efficiency aspects of product charge systems. Analyzing data compiled in studies carried out for the Resource Conservation Committee, Buchanan determined that the effect of a product charge on national solid waste flows is likely to be rather small, with estimated resource savings of between $25 million and $60 million per year. Buchanan points out, however, that the magnitude of net savings actually realized may be very sensitive to picking the correct product charge rate. At rates other than the correct rate, resource savings may fall off very rapidly, and even become negative. When the additional costs of administering a product charge are considered, Buchanan concludes that we don't know whether or not a product charge would contribute to more efficient solid waste management. He is quick to add, however, that the relevant question is not how the product charge approach compares with the theoretical ideal charge, but rather how it compares with what we are doing now, and with other practical alternative approaches to solid waste management.

Conn's paper, like Lanen's, is based upon case studies. Conn examined the experience of a number of European countries and municipalities with various forms of user and/or product charge. He found that it is extremely difficult to get the kind of hard data that is needed to make a fair appraisal of the workings of the various incentive systems that have been tried. As a result, Conn's data consist almost entirely of anecdotes concerning the transition between systems that do not include incentives and systems that do.

In general, Conn found that user-charge systems, once introduced, have not taken hold. Citing increases in littering and/or difficulty of administering such systems, communities that have had them under consideration have not adopted them, and communities that had instituted them have disconitinued them.

European experience with the product charge, according to Conn, has been somewhat more hopeful. Conn notes that a container charge in Norway has been effective in preventing any growth in the use of non-refillable containers for beer and soft drinks. In Sweden there has been a transition from non-refillables to refillables; somewhat mysteriously, use of cans has been on the increase.

Virtually all of the papers summarized above raised questions concerning the effect of incentive approaches on the costs of administering solid waste management systems. Barbara Stevens' paper presents two case studies and the results of a statistical analysis of the administrative costs associated with user-charge systems. In her case studies, Stevens shows that administrative costs depend heavily upon the "skill" with which the system is administered. Indeed, cost differences due to differences in skill probably are far more significant than are differences due to use or non-use of a user charge approach.

Stevens finds that -- on the average -- administrative costs for user charge systems probably range between 4 percent and 8 percent of collection costs. Because she has no firm estimates of the responsiveness to user-charges of quantities of waste disposed, she is unable to make an exact estimate of the net savings that result from switch from tax-based financng to a flat-fee or quantity-based fee system. Ranges of estimates presented by her suggest however that quantity reductions and/or savings of costs through change in the collections system would have to be substantial in order to offset increased administrative costs of a fee system.

Pricing and the Equity of Solid Waste Financing

Efficiency effects are not the sole grounds upon which economists have rested their case for economic incentives. Arguing that polluters should pay the costs that their wastes impose upon society, economists have also stressed that pricing approaches to financing waste management are more equitable than are other approaches. The workshop heard two papers on the question of equity and public finance aspects of pricing alternatives for solid waste management.

The first paper, by Roger Bolton, discussed considerations relevant to study of the distributional consequences of financing solid waste management via user charges in contrast to finance via property taxes. Bolton argues that a complete analysis requires consideration both of effects of charges on household behavior and on the costs of solid waste management -- the same evidence required to understand the effects of pricing alternatives on solid waste management efficiency.

Noting that a complete analysis is beyond reach given the current state of empirical knowledge, Bolton nonetheless was able to make some approximate calculations of the relationship between income level and burden of solid waste finance under a user charges policy, and to compare these with the burden that would result if solid waste management were financed through the property tax. His finding is that the distribution of the burden by income level is about the same under both alternatives. He concludes that there is "no reason to fear any noticeable increase in regressivity from substituting user charges for the property tax, particularly if it is the residential property tax which is being replaced."

Kenneth Wertz, in the second paper on equity and government finance heard by the workshop, compared the effects of user charges with those of product charges. Wertz argues that local governments and their citizenry are likely to prefer the product charge approach to approaches based on locally-levied user charges. While there are, Wertz notes, several advantages that accrue uniquely to locally-levied user charges (e.g., placing the burden of finance directly on the waste generator, and development of data that may improve the management of solid waste collection and disposal), he also notes that product charges avoid certain "liabilities" of a local pricing system. "Under federal pricing, administrative costs exist but are essentially borne elsewhere. Responsibility for the enactment of a new revenue program can also be put elsewhere. The risk of increased littering that goes with local pricing is removed by federal pricing, and the risk of having promoted a bad idea -- if in fact pricing fails to induce much reduction in the output of refuse -- is shifted to other parties." He concludes that, because of these budgetary impacts and risks, product charges are likely to gain more widespread political backing than are local user charges.

Comparison of User Charges and Product Charges

Two papers heard by the workshop compared user charges and product charges as alternative incentive mechanisms. One paper, by James Hudson, argued that product charges and user charges are complementary, and could be combined to provide a more complete set of incentives than either taken alone would provide. Hudson shows how a properly designed combination of the two approaches can avoid double-pricing of wastes and can encompass a wider range of wastes than either alone could cover.

The other paper, by Allen Miedema, compared the economic efficiency of a product charge, user charge, and recycling subsidy in a simple general equilibrium framework. Miedema finds that, in the illustrative framework he has constructed, a product charges policy yields the greatest gain in efficiency of the three pricing policies examined. He notes, however, that the treatment of user charges in his model precludes recycling activity, and thereby biases his results against user charges.

Pricing and Resource Recovery Technology

Two of the papers heard by the workshop addressed aspects of the relationship between incentive mechanisms and resource recovery technology. The first of these papers, by Tayler Bingham, presents the results of a study in which a process model was used to predict the quantity of secondary materials recovered from the solid waste stream under alternative prices for these materials. Applying techniques used elsewhere by James Griffin, Bingham estimates supply elasticities that confirm earlier findings that the recovery of secondary materials form the municipal waste stream is fairly insensitive to price changes. This finding has important implications for pricing approaches. In particular, it implies that charges levied on disposal of waste (either product charges or user charges) may not be very effective in encouraging resource recovery.

The second paper on the relationship between incentive systems and resource recovery, by Robert C. Anderson, presents some new estimates of demand and supply elasticities in the markets for ferrous scrap and waste paper. Anderson, in contrast to Bingham's approach, develops his elasticity estimates from econometric models of the wastepaper and ferrous scrap markets. While neither Anderson's or Bingham's paper contains all of the information required to make a precise comparison, it is interesting that Anderson's estimate of ferrous scrap supply elasticity is almost two times Bingham's estimate. Anderson notes, moreover, that his estimate should be adjusted upward by a factor of approximately two to obtain an estimate of the supply elasticity for ferrous scrap other than prompt. Adjusted in this manner, Anderson's elasticity is about 3.5 times higher than Bingham's. Other things being equal, Anderson's results thus imply a substantially greater shift to ferrous scrap in the face of disincentives to use virgin materials.

A near infinitude of explanations could be offered for this difference. Unfortunately, little has yet been done in reconciling process modeling approaches with econometric approaches, as the discussion of Bingham's paper makes clear. A tentative explanation may be that Bingham's process model embodies more constrained production possibilities than in fact obtain, with the result that supply is estimated to be less responsive to price than it really is. Or, of course, it may be that supply really is as obtain, with the result that supply is estimated to be less responsive to price than it really is. Or, of course, it may be that supply really is as unresponsive as Bingham estimates, the econometric results being spurious.

Pricing and Solid Waste Management

The papers discussed above for the most part dealt with the relationship between pricing policies and the efficiency and equity of solid waste management. Roughly speaking, each of the authors of these papers took as given aspects of solid waste management other than pricing policy. The fourth question raised by Goddard asks us to consider what happens in real-world policy-making and service delivery situations where all aspects of solid waste management may be subject to change when pricing is instituted. Further, it asks us to consider what criteria are relevant to evaluating alternatives in such an environment.

The workshop heard one paper on this subject by Bernard Booms. Booms described experience to date in Seattle, Washington, as that city has moved to experiment with user charges in combination with various other solid waste management alternatives. He noted that the Seattle experience provides a nearly unique opportunity for studying the implementation process. In Seattle, the entire solid waste management system has been changed to accommodate pricing. It is possible, therefore, to observe both the political and administrative processes that come into play as system management is changed. Importantly, Booms notes that the Seattle experiment does provide for monitoring and evaluation of effects on a wide variety of dimensions of solid waste management.

Research Directions

Two papers were delivered on research. One, by Oscar Albrecht, outlined the research activities of the U. S. Environmental Protection Agency. Albrecht noted that although EPA has funded a great deal of research in the economics of solid waste, much more remains to be done. Citing the immense regulatory responsibilities of the Agency, he expressed the concern tha important research needs may be overlooked. He called upon workshop participants to articulate clearly research needs.

The second paper heard on research offered George Tolley's and Steven Hasting's response to the request put by Goddard and Albrecht. Tolley and Hastings divide their discussion into two parts, one of which discussed needed research on the cost of solid waste management services and the other of which discusses research needs relating to the demand for solid waste management services. On the cost side, the most pressing need identified by Tolley and Hastings is for more refined studies of the relationship between services provided and cost. Noting that solid waste management services have a multitude of cost-causing attributes (including, for example, frequency of service, location of collection, source separation requirements, quantity, volume, container type), Tolley and Hastings called for detailed cost studies that explore the relationships between each of the attributes and service cost.

Tolley and Hastings note that even less is known about the demand side than the cost side. Here they call for a two-pronged approach. First, they recommend that crude demand curves be constructed from information on the cost of alternatives to collection and disposal. Presumably what they have in mind is something similar to the analysis of resource recovery presented in Bingham's paper, with construction of household process models describing alternatives to municipal collection and disposal of solid wastes. Second, they recommend that pricing experiments be conducted, controlled and monitored so as to produce the data needed to infer households' demand for solid waste collection services. To guide such experiments, they present a comprehensive list of questions that should be provided for in the design of each.

SUMMARY OF DISCUSSION

The papers summarized above provided the starting point for the workshop's deliberations on the various questions posed by Haynes Goddard at the beginning of our sessions. The full transcript of these deliberations runs to almost 600 pages. It is impossible for me to do more here than to try to draw out of the transcript some of the key points of agreement and disagreement among workshop participants. Complete copies of the transcripts are on file with the Municipal Environmental Research Laboratory in Cincinnati.

Pricing and the Efficiency of Solid Waste Management

Discussion of this topic touched on several aspects of the relationship between pricing and efficiency. The first aspect of this relationship to be discussed was that between pricing and households' generation of waste and selection of waste disposal methods. While several conference participants hypothesized that changes of price and/or pricing policies of the magnitudes currently observed around the nation have only a small effect on household behavior, the consensus of the workshop seemed to be that this hypothesis remains to be tested conclusively. The results of quantitative studies that have been done all are acknowledged by their authors to be subject to serious data and specification problems. While these studies provide no basis for thinking that the effect of prices in ranges currently observed are large, conference participants concluded that until more careful research has been conducted, judgement should be reserved.

A second aspect of the efficiency question addressed by the workshop was the cost of administering a pricing policy. Here again the workshop participants felt that available data are inadequate to reach any firm conclusions. However, most participants seemed to conclude tentatively that any extra costs associated with administration of a pricing policy are small.

A third aspect of the efficiency question concerns the balancing of efficiency gains induced by changes in behavior associated with pricing policies with the costs of administering them. Because of the uncertainties noted above, the workshop was unable to reach even a tentative conclusion concerning the net effect.

Pricing and the Equity of Solid Waste Financing

Workshop discussions centered about two aspects of the relationship between pricing policies for solid waste and the equity of solid waste financing. The first aspect is the public perception of equity issues. In this regard, workshop participants noted that there may be a growing public perception that finance alternatives which distribute the burden of financing solid waste management according to service usage -- as do user charges and/or product charges -- are more fair than are alternatives which distribute the burden in a manner unrelated to service usage. If so, we may expect to observe more and more interest in solid waste service pricing policies. Many workshop participants also noted that if measures to limit governmental tax revenues continue to grow in popularity, public perception of the unfairness of using general tax funds to provide free services which otherwise could be priced will be heightened.

The second aspect of the relationship between pricing and equity considered by the workshop is the effect of moving from a property tax financed system. While several participants cautioned that the evidence is far from complete, most seemed to agree that the distributional affects of switching from tax based financing to financing via revenue raised from pricing of solid waste service would not be great.

Optimal Combination of Incentive Mechanisms

This question was the subject of a great deal of discussion since natiowide product charges are being considered actively at the federal level. Many workshop participants expressed doubts that a product charge approach to pricing solid waste collection and disposal services makes much sense. Among the basic difficulties with product charges cited by those expressing this view are the following:

1. Product charges could not be levied on many household wastes. For example, product charges would not (and, more importantly, could not reasonably) apply to yard wastes.

2. Product charges set at a nationwide level would reflect national average costs of assumed methods of collection and disposal rather than local marginal costs of actual methods of collection and disposal.

Most workshop participants who expressed reservations about product charges argued that local user charges, which would apply to all household wastes presented for collection and would be set according to local cost conditions, may be a preferable pricing approach. However, the workshop, including even those most skeptical about product charges, stopped well short of concluding that user charges are a superior pricing alternative. It was generally agreed that user charges also are subject to certain difficulties, including (for example) the following:

1. User charges, given current technology, cannot differentiate among different types of waste. Since collection and disposal costs probably vary widely by type, user charges also do not reflect costs accurately.

2. Institutional considerations of administrative cost, political feasibility, market structure and so forth may weigh in favor of a product charge approach as against a user charge approach.

Workshop participants concluded that the only way to resolve the question of what sort of incentive mechanism is best is to obtain more empirical information on the political economy of pricing approaches. More information is needed on household responsiveness to incentives, the relationshp of incentives to other aspects of solid waste management, the costs of administration, and the process of implementing incentive approaches.

Pricing and Solid Waste Management

As the above paragraphs make clear, progress has been made with regard to study of particular aspects of the relationship between incentives and particular aspect of solid waste management. While workshop participants were reluctant to reach firm conclusions about the responsiveness of households' waste generation to user charge/product charge levels, evidence to date does support some weak positive conclusions.

This situation contrasts sharply with the state of our knowledge concerning the relationship between pricing policy and the entire process of solid waste management. We do not know, for example, what the relationship between pricing policy and efficiency of collection and disposal may be. Some observers have hypothesized that the use of prices makes costs of solid waste management more "visible", and hence promotes efficient management of solid waste collection and disposal. We do not know whether or not the effect of prices on household generation behavior depends upon the nature of collection and disposal option (e.g., self-hauling, recycling centers, source separation programs), although we hypothesize that it does. Still another interesting and important aspect about which next to nothing is known is the relationship between information about waste content of goods and services, pricing, and solid waste management. Workshop participants felt that the scope of research on pricing and solid waste management must be expanded to cover these as yet unexplored areas.

Research Directions

Implicit in the papers we heard and the discussion we conducted is a long list of specific research topics. These topics certainly would include the following:

1. Effects on household behavior of changing from tax-based finance to pricing.

2. Effects on household behavior of availability and/or prices of methods for solid waste handling such as home compaction, garbage disposals, self-hauling, separate collecting of yard wastes, and source separation and recycling programs.

3. Effects of alternative combinations of system design, operating procedures, and waste loads on the cost of solid waste management.

4. Effects of pricing policy on cost of solid waste management.

5. Effects of information on waste content and collection/disposal cost on household behavior.

6. Institutional considerations in the design and operation of solid waste management systems.

Workshop participants also spent a substantial amount of time discussing research methods. Noting that the data that have been used in studies conducted to date are deficient in imporant respects, workshop participants seemed to be unanimous in recommending improved research design. Among the specifics raised by workshop participants are the following:

1. An effort should be made to improve and expand the collection of data on current operations and costs of solid waste management systems.

2. Preparation should be made to capitalize on the experimental opportunity presented when a community decides to change its solid waste management system, or the method or level of pricing of solid waste management services. Case studies of these natural experiments should be conducted.

3. Case studies of changes in solid waste management in municipalities abroad should be conducted.

4. Serious consideration should be given to conducting fully designed and controlled experiments.

CONCLUSIONS

In general, workshop participants felt that the time for an expanded research effort on pricing in solid waste management has arrived. While participants did differ in their views about the seriousness of inefficiencies caused by failure to price solid waste management services correctly, there was a consensus that pricing policy will become vitally important in the future. This will come about for several reasons, including increasing cost of landfill, and growing pressures to reduce tax burdens. If we begin now to design and execute a plan of research designed to answer conclusively the practical questions raised elsewhere in this volume, we will be ready to help communities manage their solid waste services more efficiently.

CAN ECONOMIC INCENTIVES HELP RESOLVE SOLID WASTE MANAGEMENT PROBLEMS?

by

HAYNES C. GODDARD

The purpose of this symposium is to bring together the principal and most active researchers in the country on the question of the proper role of economic incentives in a comprehensive approach to resolving municipal solid waste management (SWM) problems. Outside of the investigations of the comparative handful of researchers assembled here today, this area has received only a small fraction of the attention that has been devoted to economic incentives for the management of air and water residuals. Furthermore, except for the product charge concept (a manufacturer's excise tax on packaging materials), the question of economic incentives for SWM has tended to be accorded the same degree of hospitality by governmental research and program administrators as for other economic incentives: a large yawn.

None the less, with the gradually increasing attention paid to the question by members of this group, our understanding of the potential for incentives in this area is growing, and has led the organizers of this symoposium to conclude that that the time is propitious for a concentrated review of the major issues. By bringing together for the time those with research interests in the area, we hope to enlarge our collective and individual perspectives and understanding of the area.

We are assembled here with the common belief that it is worth testing the hypothesis that economic incentive systems in SWM will raise economic, engineering, and administrative efficiency and perhaps also equity by making the costs of the various characteristics of SWM explicit to the waste generators. Such characteristics are weight, volume, packaging content, location of pick-up, frequency, and any other locally unique characteristics. We hope that major outcomes of this symposium will be a specification of the relevant research and policy questions that need to be investigated, and a set of relatively specific recommendations indicating how this research should be conducted.

Most of you are aware that, in general, the official reception of economic approaches to residuals management has never been a very hospitable one and at times has been downright hostile. Our colleagues in engineering and law have been much more successful in convincing policy makers of the applicability and validity of their proposed solutions to the residuals management problems and while, of course, physical and regulatory measures are necessary conditions for efficient and effective pollution control, they are not sufficient. Undoubtedly part of the problem we confront can be explained by the low level of economic literacy that characterizes the population in general, but this notwithstanding, the major share of the blame for the lack of success which economists have suffered in obtaining receptivity for their ideas must lie on the economists themselves.

Two of the internal impediments that some have observed to diminish the receptivity of proposed economic solutions are:

- a rather exclusive interest on the part of academic researchers in the theoretical aspects of pollution control, with a corresponding relative neglect of the empirical side of the problem (of which I myself am guilty);

- a tendency to build models with substantial specification error, either because of mathematical convenience and/or because data on the correct dimension to be tested is unavailable.

A major external impediment on the research side is that our colleagues in engineering typically are given a limited exposure to economic analysis, and thus conclude that they can perform what economic analysis is needed to resolve pollution problems.

If we are to increase our effectiveness in making contributions to the resolution of pollution problems, we must find ways to remove these and other impediments, and we must become more effective spokesmen for economic understanding, but, of course, we must have an understanding to convey--that is why we are here.

Research on economic approaches to SWM does not have a long history, dating back only 4-5 years, but nonetheless, this research has been pursued in several directions. These directions have included user charges for SWM, manufacturing excise taxes (product charges), litter control incentives, relative efficiencies of alternative institutional arrangements, the impacts of federal tax policies on waste generation and materials recovery, and the incremental costs of collection and disposal among others. Our understanding in each of the areas is growing, but is still insufficient to make reasonably complete evaluations of the impacts of alternative incentive mechanisms.

The speakers today and tomorrow will be touching on a large number of current research and policy questions, and I will not attempt to enumerate them here. I do want to mention, however, some of the major questions that have not been answered, and hope that we will remember to reference them frequently throughout our proceedings. These questions are:

- Do incentive systems that are designed to alter waste generation behavior in fact raise the economic efficiency of SWM, that is, produce large net benefits?

- What is the optimal combination of alternative incentive mechanisms? How should the product charge and the user charge be related to one another in the most efficient configuration of complementary and substitute incentive systems?

- How do these incentive mechanisms relate to the choice of resource recovery technologies?

- What is the optimal combination of all SWM alternatives, and what criteria should be employed to make the choice?

- What is the best way to pursue the testing of the effects of the incentive mechanisms, with historical or experimental data?

I hope that this symposium will help us much in our search for answers to these and other related questions. Hopefully, we can also find some ways to remove impediments to the employment of economic knowledge in the quest for efficient and effective environmental management.

SECTION 2

PRICING AND THE EFFICIENCY OF SOLID WASTE MANAGEMENT

"The Economic Efficiency of User Fees: Some Preliminary Empirical Results" (William N. Lanen).

"Evaluating the Efficiency of the Solid Waste Charge" (Steve Buchanan).

"Economic Approaches to Solid Waste Management: European Experience" (W. David Conn).

"The Administrative Costs of User Charges" (Barbara J. Stevens).

THE ECONOMIC EFFICIENCY OF USER FEES:
SOME PRELIMINARY EMPIRICAL RESULTS

by

William N. Lanen

One of the most fundamental propositions of economic theory is that the demand for any good or service declines as the price of that good or service increases. This is, undoubtedly, one of the major reasons economists traditionally look to pricing solutions rather than regulatory solutions for the control of environmental pollutants. Today, economic solutions involving charges are being employed to deal with air, water, noise, and land pollution problems.[1]

Individuals charged with the management of systems (for example solid waste management systems) have, on the other hand, tended to distrust pricing approaches. The reasons for this distrust include notions of equity (for example, that charges for solid waste collection are regressive) or practicality (e.g., that user charges are administratively burdensome).[2] It then becomes important to determine whether user charge systems, especially incremental charge systems, lead to improvements in economic efficiency.

The approach an economist would take to make that determination has been given the name "cost-benefit analysis." Cost-benefit analysis is nothing more than a set of procedures for performing an analysis of the merits of alternative approaches to problem solution. As such, it is done, perhaps only implicitly, by decision-making units at all levels. The difference between the results of the analysis (i.e., the reason why different groups come up with different "optimal" solutions) is that each group accrues different benefits and incurs different costs. As we discuss below, the conflict between system managers and economists about the optimal solution to the financing of solid waste management may often be a result of this difference in the organizational unit considered.

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[1] See, for example, the discussion in Anderson, *et. al*.

[2] American Public Works Association, *Solid Waste Collection Practice*, 4th Edition, Chicago, 1975.

The purpose of this paper is to present some preliminary results of a study conducted by MATHTECH, Inc. for the Municipal Environmental Research Laboratories of the U.S. Environmental Protection Agency. A case study approach was employed using five cities, each with a different structure for a user fee. (The term "structure" will be defined below.) The study was primarily empirical in nature and its purpose was to evaluate the impact of user fees residential solid waste behavior.

In the first section we discuss the concept of economic efficiency and its role in evaluating user fee systems. We then describe the different types of fee structures. Finally, we evaluate the qualitative effects which we would expect each of the fee structures to possess.

In the second section a selective review of the literature is presented. It is selective in that it discusses only work which has attempted to estimate price or income elasticities. As we will show, while there is some statistical evidence of positive income elasticities of waste generation, no study to date has provided convincing evidence of a statistically significant non-zero price elasticity. Non-zero price elasticities, while they cannot be used to measure economic efficiency, are a necessary condition for the employment of user fees to lead to an improvement in efficiency.

In the third section the results of our study are presented.[3] Both the models and the statistical results are discussed. We will see that there is some additional evidence of positive income elasticities. While some evidence points to the existence of statistically significant price elasticities, it is not strong.

Finally, in the last section we present our conclusions with respect to the effects of a user charge system on residential solid waste behavior and the consequent implications for their role in increasing economic efficiency.

USER FEE SYSTEMS AND ECONOMIC EFFICIENCY

To an economist, a system that is economically efficient is one in which net social benefits are maximized. Net social benefits are, of course, nothing more than the difference between social benefits and social costs. Under traditional cost-benefit analysis, the measure of social benefits is "consumers' surplus." In other words, it is the difference between what consumers would be willing-to-pay for a particular good or service (e.g., carryout service) and what they are required to pay (if they take the service).[4] Social costs are defined in terms of opportunity costs. Making use of these two concepts, we next show how they might be used to evaluate the economic efficiency of a user fee system.

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[3] At this time, all of the results of the study must be considered tentative.

[4] The terms "benefits" and "costs" can, in practice, be misleading since, for example, depending upon the baseline taken, benefits can be, and often are, reductions in costs.

An Illustration

Consider the question of carryout service. If refuse collection services are provided by the city, it has three basic alternatives: provide the service to all residents; provide the service to no residents; or, charge a fee for the service and let the individual resident choose. The comparative benefits can be assessed using the information presented in Figure 1.

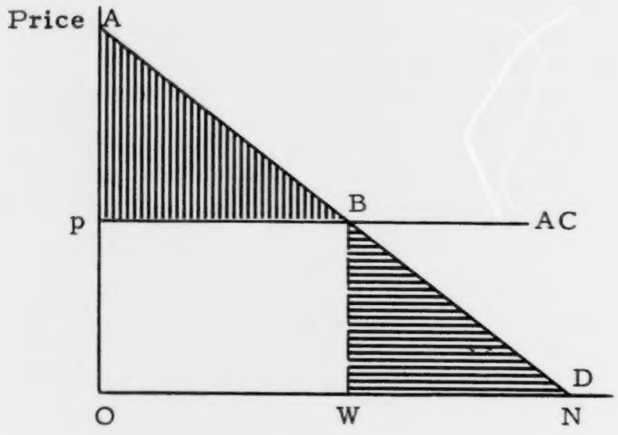

Figure 1. Evaluating economic efficiency

In Figure 1, the demand for carryout service is drawn as a linear function of price only for simplicity. It is assumed that at zero price, all residents will demand the service. While this may not be true (if, for example, some residents feel there are additional costs to having collectors enter their yards) nothing in the analysis is altered by this assumption. Suppose that, if the service is offered for a fee, the fee (p) will be set to equal the average cost (AC) of providing the service. (Average costs are drawn as constant in Figure 1, implying that average costs equal marginal costs. We have excluded from the figure any administrative costs which might be associated with the use of a fee.)

Consider now the net social benefits associated with the three alternatives outlined above. The first alternative, providing the service to everyone without an explicit change, is equivalent to charging a zero price.

Therefore, the demand is 100%. The total willingness-to-pay (i.e., the area under the demand curve) is equal to the area OAD. The total cost of providing the service is N x AC where N is the number of residents. (There are no administrative costs since the service is provided to everyone and no monitoring is required.) Therefore, the net benefits to society are equal to the total benefits less net costs and depend on the relative size of the two shaded areas in Figure 1.

Now consider the net social benefits of not providing the service at all. In this case the net benefits are zero -- no costs and no benefits.[5]

Finally consider charging a price p (assumed to be equal to average cost). The percentage choosing the service will be W. The total benefits (i.e., willingness-to-pay) are OABW. The total costs are AC x (W)(N). The net social benefits are the vertically shaded area pAB. Note that the benefits associated with this arrangement are greater than those associated with providing the service to everyone by the amount WBD (the horizontally shaded area) neglecting the administrative costs.

Similarly the net benefits associated with the charge system are greater than providing no service (again neglecting administrative costs) by the amount pAB. The question of the best choice depends then on the level of administrative costs. If they are less than pAB, a charge system is, on net, beneficial when compared to providing no service. If they are less than the area BCD, then the charge system has greater net benefits than the free provision. Of course, the level of the administrative cost and the relative magnitude of the shaded area are empirical questions.

Suppose, however, that in the process of trying to evaluate the net social benefits associated with a particular fee structure, that the analyst is missing some of the crucial information; e.g., the actual demand curve for the service. Is there some necessary condition that must hold for a user fee to improve economic efficiency (not equity)? The answer is yes. Basically, it must be true that the demand curve has a negative (i.e., non-zero) slope. Consider what happens if the slope (or elasticity) is zero in the relevant range.[6] If the elasticity is zero, the waste presented for collection remains the same and, therefore, total costs remain the same. All that happens is that there is a transfer payment from residents to the solid waste system, and under traditional cost-benefit analysis such a transfer has no effect on benefits.

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[5] Again, this result is dependent on the definition of the baseline.

[6] Obviously, at some price, demand for the service will fall. In discussions, such as this, with policy implications, it is of interest to determine whether there are significant price effects within the range of user fees normally encountered in practice.

A Classification of Fee Structures

As discussed above, the approach followed in this study has been a case study approach of five cities, each of which has a different type of fee structure. By "different" we mean merely that the resident in each of these cities is faced with a different set of choices concerning the disposal of the solid waste generated within the household. Before discussing the findings in each of the five cities, however, it is useful first to discuss the classification systems used to develop the five different fee structures. Once this has been done, we can analyze what the qualitative effect of a fee increase would be.

The nature of the fee systems used by the roughly 1400 communities identified in the study that employ user fees for the collection of residential solid waste vary greatly. However, within that variation, there is one characteristic which is (a) easy to identify, (b) useful in the development of hypotheses concerning behavior, and (c) restricted in relevant possibilities. This characteristic is, therefore, an obvious one to use for the classification of user fee systems for the purposes of selecting the case study cities. This characteristic is the set of decision choices the resident has for the disposal of solid waste. Although there may be others, we have selected five different possibilities as including (hopefully) most of the fee structures currently used. Below we identify and define each type.

The first, simplest, and by far the most widely used fee system is the uniform or flat fee structure. In this system, the resident (assuming service is mandatory) has no choice over his disposal options.[7] The goal of this type of fee structure is basically one of revenue raising. In other words, the flat fee service is an alternative to general tax revenues for supporting the solid waste system.

A more complex system is one in which the resident has the option to choose the number of containers (i.e., the capacity) for waste for pickup. While it is not necessary to assume that the resident must remain within that constraint once and for all, it is assumed that there are some transaction costs associated with frequent changes from one level of capacity to another that are sufficiently large to discourage such changes. We will refer to this as a capacity-based structure.

A third type of fee structure is one in which the resident can choose alternative levels of service. Service levels can be defined in terms of the point of collection (curbside or backyard) or frequency of collection (e.g., weekly or semi-weekly). Most cities that have a service-based system provide a choice in terms of location. In this system, the number of containers that can be presented is specified (although it may be unlimited). This is referred to as a service-based structure.

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[7] Certainly, the household can choose illegal modes of disposal.

Metered-bag systems are those systems where the resident presents all waste to be collected in a specially-marked bag. This system is quite similar to the capacity-based system discussed earlier. The difference, and this is an important one, is that the resident can alter, at no cost (other than the cost of the bag) the number of containers presented each time. While this system is not a true *quantity-based* system, where the resident pays for collection according to the weight or volume of the waste presented, it is a step closer to that ideal because of the freedom offered at each collection period.

Finally, some municipalities employ fee structures that are combinations of two or more of the other systems. For example, in Tacoma, Washington, the resident chooses both the number of containers and the level of service (in terms of pickup location). This type of system may be expected to be more expensive yet more flexible than a system offering only one choice. This will be referred to as a *combination-based* structure.

Analyzing the Effect of Different Fee Structures

In theory, one could qualitatively analyze the impact upon resident behavior from the change in the level of the fee for any type of fee structure by first developing a utility maximization model with each of the fee features. Then, comparative statics could be used to determine the direction of change in the amount of waste generated. Such an approach was used, for example, by Kenneth Wertz (1976) when analyzing the effect of price and service level upon waste generation behavior. The problem with such an approach is that, of necessity, most of the fee systems that exist include in their rate structures such large discontinuities (e.g., the number of containers) that applying such methods may not be particularly fruitful when examining actual systems. The results of the Wertz analysis are helpful, however, in that they provide a check on a more simple approach to the qualitative determination of the effects of a fee change.

Consider, for example, an "ideal" fee structure where the resident pays by the pound (or cubic foot, or both) for the amount of waste disposed. Further, suppose that he is allowed to choose the point of collection (for a fee). A system of demand equations that might be expected to model such a decision process adequately would be like the two equations:

$$q = f(\overset{-}{p}_w, \overset{+}{y}, \overset{+}{s}) \tag{1}$$

$$s = g(\overset{-}{p}_s, \overset{+}{y}) \tag{2}$$

where q represents the quantity of waste disposed, p_w the price per unit of waste, y is disposable income (after payment of any flat fee for disposal), s is a measure of service level (e.g., the number of feet from the curb), and p_s is the unit price of the service level. Noted above each of the independent variables in both equations are the effects we would expect changes to have. For example, following elementary theory we would expect that an increase in the price of either quantity or service would decrease the demand for the respective good, and similarly for income. In equation (1), we show that the effect of an increase in service level leads to an increase in the amount of waste generated. This is consistent with the findings of Wertz. Intuitively, its justification is quite straightforward. The disposal of residential solid waste requires the labor of two different units: the collector and the household. Use of household labor is costly just as is the use of the collectors' labor. Increasing the service level while holding all other variables constant, means that the cost to the household of presenting an additional unit of waste has fallen. We would therefore expect to observe an increase in the amount of waste presented.

We can now use equations (1) and (2) to determine the effect of a change in the price of either quantity or service level. The effect of a change in the price of quantity is known directly from the demand curve. The effect of a change in the price of service level upon the amount of waste generated depends on the indirect effect of the service price on the level of service. Thus,

$$\partial q/\partial p_s = \partial q/\partial s \cdot \partial s/\partial p_s < 0 \tag{3}$$

The effect of an increase in either price therefore is expected to be a decrease in the amount of waste presented for collection. These results were for the ideal system. We now evaluate the five types of fee structures described above.

In the case of the uniform fee, the only equation is:

$$q = f(\overset{+}{y}) \tag{4}$$

Note that the only variable influencing the amount of waste presented for collection is the disposable income. Suppose we define,

$$y = m - p \tag{5}$$

where m is household income before the fee and p is the flat fee. Then,

$$\partial q/\partial p = \partial q/\partial y \cdot \partial y/\partial p = - \partial q/\partial m \tag{6}$$

That is, the effect of an increase in the flat fee is equivalent to the effect of an equal decrease in income. In terms of elasticities, however,

$$\eta = \partial q/\partial p \quad \cdot \quad p/q = -\,\partial q/\partial m \quad \cdot \quad p/q = -\,\eta_m \cdot \quad p/m \tag{7}$$

This means that if the income elasticity of waste generation is, say, on the order of .30, then the elasticity with respect to a change in the level of the flat fee is insignificant.

The capacity-based system differs from the ideal because the resident does not face an explicit charge each collection. Rather, he faces what is essentially a capacity constraint. Therefore, his choice can be modeled as:

$$q = f(\overset{+}{c}, \overset{+}{y}) \tag{8}$$

$$c = g(\overset{-}{p_C}, \overset{+}{y}) \tag{9}$$

Again, the signs above the independent variables represent our assumptions about the effects of changes in these variables on the amount of waste generated. In these equations, C represents the number of cans selected. Ignoring the discontinuity of the number of cans, we can analyze the effect of an increase in the price per can on the amount of waste generated. It is:

$$\partial q/\partial p_c = \partial q/\partial c \quad \cdot \quad \partial c/\partial p_c < 0 \tag{10}$$

The product of the two terms in (10) is negative by virtue of the effect of price on the number of containers selected. However, if the first factor is less than one, the resident can moderate any inhibiting effect of the price change. This factor $\partial q/\partial c$ measures the density change resulting from a change in the number of containers. That is, if it is less than one, part of the effect of the change in price is to have residents packing each container slightly more full. This would be a perfectly rational thing to do since, as the price of an additional can increases, the relative cost of the resident's own labor in the preparation of his waste for collection falls.

This suggests that one of the "weaknesses" of the capacity-based system is that it provides a means for the resident to avoid the full effect of the price increase. Of course, the quantitative importance of this effect is an empirical question.

The model for a service-based fee would be

$$q = f(\overset{+}{s}, \overset{+}{y}) \tag{11}$$

$$s = g(\overset{-}{p_s}, \overset{+}{y}) \tag{12}$$

Here we are interested not so much in the effect of changes in the level of the fee on the choice of service level by the resident, which we know must be negative, but the effect on the quantities of waste generated. But this is just,

$$\partial q/\partial p_s = \partial q/\partial s \;\; . \;\; \partial s/\partial p_s < 0 \tag{13}$$

Therefore, we see that the effect is dependent upon two quantities; the effect of price on service and the effect of service on quantity.

The bag system differs from the capacity-based system in two important respects. First, the resident chooses the number of containers to use each collection period. The second is the fact that each bag used includes the cost of the bag. With a container, the container was not "consumed" when filled. With the bag it is. Therefore, the system of demand equations for this system can be specified as:

$$q = f(\overset{-}{p}_B, \overset{+}{B}, \overset{+}{y}) \tag{14}$$

$$B = g(\overset{-}{p}_B, \overset{+}{y}) \tag{15}$$

where p_B is the price of a bag. Note that the price of bags affects the demand for two separate goods, the collection of waste and the number of bags. Therefore, we would expect the effect of a price change to be somewhat more complicated. In fact, it is,

$$\partial q/\partial p_B = \partial q/\partial p_B + \partial q/\partial B \, \partial B/\partial p_B < 0 \tag{16}$$

The combination systems combine the effects of two or more of the types of fee structures. Assuming that the combination is for the number of containers and the location for pickup, the model for analyzing the effect of fee changes would be:

$$q = f(\overset{+}{c}, \overset{+}{s}, \overset{+}{y}) \tag{17}$$

$$c = g(\overset{-}{p}_c, \overset{+}{y}, \overset{+}{s}) \tag{18}$$

$$s = h(\overset{-}{p}_s, \overset{+}{y}, \overset{+}{c}) \tag{19}$$

Measuring the effect of a change in the price for containers is now complicated by the fact that the container fee will affect both the number of containers selected and the level of service chosen. The effect of a change in the fee for a container is

$$\partial q/\partial p_c \;=\; \partial q/\partial c \;\; \partial c/\partial p_c + \partial q/\partial s \;\; \partial s/\partial c \;\; \partial c/\partial p_c < 0 \;; \qquad (20)$$

the effect of the change in the fee for level of service is

$$\partial q/\partial p_s \;=\; \partial q/\partial s \;\; \partial s/\partial p_s + \partial q/\partial c \;\; \partial d/\partial s \;\; \partial s/\partial p_s < 0 \;. \qquad (21)$$

We see that in both cases the impact of an increase in either fee is to reduce the amount of waste presented for collection.

REVIEW OF THE LITERATURE

While there have been innumerable studies of the cost of providing solid waste collection services (along with many prescriptions for decreasing agency, not necessarily social, costs with particular technologies), there have been relatively few studies that empirically address the effects of pricing on residential solid waste behavior. Without such information, however, the analyses of the "optimal" type of fee structure would be impossible to conduct in terms of cost-benefit analysis. The purpose of the following is to provide a brief, and admittedly selective, review of the empirical literature that has developed in this area. The reason for focusing on the following studies is that they form the basis for much of the current discussion regarding solid waste pricing and, because they provide numerical estimates of elasticities and other economic data, have come to be relied upon in policy-making discussions. Therefore, it is important that they be assessed critically in order that the faith placed in the results be commensurate with that due.

Wertz

The Wertz article is primarily concerned with the development of qualitative implications for the effects of changes in service fees or quantity fees. However, throughout the paper are several brief examples which provide some support for the theoretical propositions developed. The ones which we are primarily interested in are those relating to income elasticities, price effects, and service level effects.

With respect to income effects, Wertz used data from 10 suburbs of Detroit which had similar financing and collection policies. Using a linear functional form for the demand curve, Wertz found implied income elasticities of .279 and .272 (depending on the actual sample used). In a conclusion that does not seem to be entirely warranted, Wertz states "The foregoing mixture of theory and observation suggests the expected: residential refuse quantities should decline as t (price) increases."

The "foregoing mixture" of theory appears to be the derivation of the usual classification of effects into substitution and income effects. This is perfectly straightforward following usual demand theory. What is not clear is how the observations about income elasticities from cities employing no incremental user charge can support expectations about price elasticities.

Following this conclusion, Wertz examines some additional evidence bearing on the price effect. He cites the fact that per capita generation in San Francisco, which employs an incremental user fee, was substantially less than "for all urban areas where general financing prevails." As Wertz notes, there are too many variables to place too much belief in the numerical accuracy of the implied price elasticity of .15. In addition to the lack of data, however, is the fact that the comparison was between two different years made comparable by applying "an average growth rate." In addition, the growth rate was applied to a figure which was composed of measured tons and estimated (from volume) tons.

The estimates Wertz provides on income elasticities appear to be consistent with the findings of others and are based on statistically sound methods. The empirical evidence of a non-zero price elasticity is not, however.

Tolley, Hastings, and Rudzitis

In an updated version of an earlier study, Tolley, et al., provide estimates of income elasticities based on cross-sectional data from several wards in Chicago. Because waste collection services are financed out of general revenues in Chicago, no estimates of price elasticities were possible.

The findings of Tolley, et al., were consistent with the earlier work. Namely, the estimated income elasticity in Chicago appears to be .3 and .7, depending on the season.

Again, these findings are also consistent with those of others that there is an income elasticity which is positive but less than one.

McFarland

One of the most oft-cited studies concerning the existence of a significant price elasticity is the study by the University of California on solid waste practices in that state. Chapter IV, which formed the economic basis of the report, was authored by McFarland and has come to be known by that name. We will therefore continue to use it.

The approach McFarland used to estimate the price elasticity was to apply ordinary least squares to the following equation:

$$Q_d = a_0 X_1^{a_1} X_2^{a_2} X_3^{a_3}$$

where Q_d is the annual per capita quantity of waste generated, X_1 was average revenue, X_2 was per capita income, and X_3 was population density. The results of the regression were:

$$\ln Q_d = 6.9 - \underset{(3.2)}{.455} \ln X_1 + \underset{(.36)}{.178} \ln X_2 - \underset{(1.5)}{.212} \ln X_3$$

where t-statistics are noted in parentheses. McFarland used this result to state "This indicates that people will definitely respond to price incentives or disincentives in their use of the service." There are, however, several problems with these results -- problems which essentially vitiate the results.

First, the price proxy used was average revenue. Unfortunately, McFarland did not specify the actual 13 cities used in the analysis. However, since only two out of the 58 in the entire study appear to employ an incremental user fee, the majority had to be flat-fee cities. In that case, there is no price elasticity. A second problem is that many flat-fee cities impose quantity limits. This means that service levels are not held constant.

Finally, there is undoubtedly a good deal of simultaneity. Most municipal systems are designed so that the flat fee is, at least somewhat, related to system costs. But system costs are related to the level of waste collection. Therefore, by not including a second equation in the model and using simultaneous methods, the results do not have the usual desirable properties.

These problems may also have led to the finding of an income elasticity not significantly different from zero, a finding which conflicts with other studies.

McFarland goes on in the analysis to discuss the effect of incremental fees on litter -- the primary externality to be expected from the imposition of a user fee. To do this, she classifies cities as internalizing or externalizing, depending upon their mode of financing and quantity limitations. Externalizing cities are those cities not "providing unlimited or generous service at zero marginal costs." She then found a significant difference in the costs associated with the solid waste management system between the two types of cities. She attributed this difference to the extra costs of litter cleanup in the externalizing cities.

The results of this analysis have been criticized elsewhere (see; e.g., Goddard). However, an important point that we have not seen mentioned is that flat-fee cities imposing quantity limits (while perhaps by definition incremental fee cities; i.e., with an infinite incremental fee) are not what is generally meant by incremental fee cities.

The empirical results of McFarland, therefore, do not appear to be sufficient evidence of the existence of non-zero price elasticities either directly from demand equations or indirectly through litter effects.

Stevens

In an unpublished research paper, Barbara Stevens has presented some results, both theoretical and empirical, concerning service level pricing. In the theoretical analysis she extends the results of Wertz by explicitly including frequency of collection and location of pickup simultaneously. She concludes the theoretical section with:

> All mandatory collection systems, whether the fee is explicit or implicit, cause the consumer to generate less wastes when prices are increased (provided that either the price elasticity of demand for service or that the relation between refuse generation and income is small) and cause the consumer to generate more wastes in response to a costless increase in service level. Only the service level fee pricing scheme has the joint advantage of encouraging consumers to value goods implicitly according to the disposal cost of their refuse component and of implementability.

It is important to note her qualifier "mandatory." She goes on to assert:

> When a pricing scheme does not require mandatory participation of households, none of the above conclusions, with respect to any of the pricing models, can be stated with any confidence. In any such non mandatory arrangement, increases in the price of refuse collection services can lead to a decrease in the proportion of households selecting organized collection services. The households opting out of the system may choose to self haul to legal disposal site (sic), to dump in illegal locations, to burn refuse, etc. Any or all of these alternative disposal technologies may result in a perceived increase in disposable income and a consequent increase in refuse generation. In addition, some of these alternate disposal technologies may result in increased total costs of collection and disposal of refuse to be borne by the society as a whole.

The reason for such a counterproductive generation effect, at least in terms of economic theory, is unclear. For if the resident could make use of the alternative facilities at lower cost than at the new user fees, the same alternatives were available at the lower cost. That is, let $p(Q)$ be the price of disposing of an amount Q_c through "conventional" means. Let $L(Q)$ be the "price" of some alternative form of disposal (e.g., littering). Then the resident will choose quantities Q_c, Q_L to be disposed of conventionally and littered so that

$$TC = p(Q)Q_c + L(Q)QL_L$$

is the total cost of waste disposal. Total waste generated is just $Q_c + Q_L$. Now suppose there is a price increase in conventional disposal. Regardless of the functional forms of the price functions $p(Q)$ and $L(Q)$, the total cost cannot fall. (It is true, however, that there will be more waste disposed through illegal means and, therefore, social costs may increase.)

The difference between mandatory and non-mandatory systems is that, under the latter, the resident has more substitution possibilities available. Thus, in such systems, we would expect the inhibiting effect of any price increase to be more moderate than with a mandatory system.

With respect to the empirical portion of the paper, Stevens provides a useful test of the efficiency of service-based fee systems. Stevens estimates three demand curves: one for waste presented for collection; demand for service frequency; and demand for service location. Using the latter two, we can estimate consumers' surplus and, hopefully, say something about the effect on economic efficiency of service-based plans.

For example, the demand curve for location of pickup is

$$BY = 271 + .003Y + 1.4QH + .04FRE - 3.3P_{BY} - .028DEN \qquad (22)$$

where BY = percent of households selecting backyard service
Y = mean annual family income
QH = annual tons of refuse per household
FRE = percent selecting higher frequency of service
P = price (per month) for carryout service
DEN = persons per square mile

Significant explanatory variables were income and price.

Substituting the mean values for each of the variables except price into (22), we get

$$BY = 268 - 3.3p_{BY} \qquad (23)$$

Equation (23) can be used to estimate consumers' surplus. First note that (23) is linear and therefore consumers' surplus is just the triangle bounded by the demand curve, the price, and the price such that BY is just zero. That is,

$$CS = BY \times (p_{max} - p_{BY}) \times .5 \tag{24}$$

where p_{max} is the price such that BY is just zero. From (23) p_{max} = \$81. Using mean values for BY and p_{max}, we find

$$CS = .28 \times (81 - 2) \times .5 = \$11.06/\text{year}$$

The \$11 is per household (since the quantity term is percentage of households). To determine whether the offering of such a service leads to an increase in efficiency, we need to compare this benefit to the administrative costs of providing the optional service (we assume that the price includes the additional collection costs). While there is no data, we can infer likely effects. Stevens' sample generated 1.71 tons per household annually. Assuming average collection and disposal costs of \$30, total annual costs per household would be \$51. The benefits of \$11 annually per household represent 22 percent of this. Edwards and Stevens found administrative costs to be between 3% and 18% of collection and disposal costs. Thus, it appears that providing the optional service increases economic welfare.

Because of the assumptions necessary to estimate consumers' surplus in this case, we would not want to say that the Stevens' results can be used to infer that service-based plans increase economic efficiency. We would argue, however, that they are highly suggestive.

Based on the theory and previous studies relatively little can be said about the magnitudes of the price and income elasticities. There exists no statistically valid evidence of a quantity effect. The Stevens' result suggests that price is important to the resident in selecting service levels.

In the next section, we present our analyses of the effects of five different types of fee structures. As with the studies reviewed here, the results (or lack of results) depends on the amount of data available.

RESULTS

In this section, we present some preliminary empirical results of our study. The emphasis in this section will be on results about elasticities, both income and price, that can be derived from each of the case studies.

Burbank, California

The City of Burbank, California employs a flat-fee system for residential solid waste collection. Service from the City is mandatory for all residents in single family dwellings and is available to residents in multifamily housing. Service is offered once-weekly and there is no limit to the amount of waste that may be presented for collection provided only that it is properly packaged. These two factors mean that City residents have no incentive for either reducing the amount of waste generated or to engage in illegal disposal methods in response to a fee increase.

As we will show below, the income elasticity estimated for Burbank, given the assumptions and model specification discussed below, is consistent with previous findings. Recall that with a flat fee there is no non-zero price which the resident faces but rather a one-time charge that operates through an income effect. Therefore, there is no price elasticity to be estimated.

The basic equation estimated for the Burbank case study is:

$$Q = a(RS)^{b} s^{c}$$

where RS represents retail sales, which was taken to be a surrogate for income. Taking logs on both sides,

$$\ln(Q) = \ln(a) + b \ln(RS) + c \ln(s) \qquad (25)$$

In this section, we present the results of the econometric investigation of equation (25).

The first step is to select seasonal variables. For the estimation of the equation, we have used dummy variables to represent Winter (December, January, and February), Spring (March, April, and May), and Summer (June, July, and August).

Using monthly totals on waste collected and including the 30% of "commercial" waste that is estimated by city personnel to be residential, the results of applying ordinary least squares to equation (25) gives (standard errors are in parentheses):

$$\ln Q = 6.18 + \underset{(.11)}{.171 \ln RS} - \underset{(.025)}{.06\ \mathrm{WINTER}} + \underset{(.025)}{.08\ \mathrm{SPR}} + \underset{(.024)}{.07\ \mathrm{SUMMER}}$$

$$R^2 = .38$$
$$N = 83$$

As shown in the results of the regression, the coefficient in the income surrogate is not significant at the 95% confidence level (the t-statistic is 1.62). Before failing to reject the null hypothesis of no income effect, some additional investigation was performed. The most plausible reason for the finding of no effect is that the effects of income are felt on waste generation only after some lag. Therefore, we use lagged (by one month) retail sales in the next regression. The results are:

$$\begin{aligned} \ln Q = 5.73 &+ \underset{(.106)}{.221} \ln(RS{-}1) - \underset{(.024)}{.058}\ \mathrm{WINTER} + \underset{(.024)}{.081}\ \mathrm{SPR} \\ &+ \underset{(.023)}{.068}\ \mathrm{SUMMER} \end{aligned} \qquad (26)$$

$$R^2 = .36$$
$$N = 81$$

The coefficient on the income variable implies an income elasticity of .22 and is statistically significant at the 95% level. This figure is consistent with previous findings as discussed in Section B above.

To check the sensitivity of the results to the particular quantity variable, the results of several other regressions are summarized in Table 1. As shown there, none of the implied income elasticities are significantly different from one another. (All regressions include the same set of independent variables as in equation (26)).

TABLE 1. ALTERNATIVE INCOME ELASTICITIES

	Estimated income elasticity	t-statistic	R^2
Excluding 30% of commercial waste	.221	2.05	.36
Daily totals including 30% commercial	.272	2.83	.28
Daily totals excluding 30% commercial	.273	2.81	.27
Per capita monthly including 30%	.233	2.13	.35

Note: For all regressions, the number of observations was 81. The period was February, 1972 to December, 1977 excluding December, 1973 and January, 1974.

These results lend support to previous findings in the range of .2-.4 for the income elasticity. Because this analysis is a time-series analysis we would expect the elasticities estimated to be short-run elasticities and, therefore, somewhat lower than those estimated by cross-sectional analyses.

Sacramento, California

The City of Sacramento, California allows residents to choose, for a fee, the number of cans to be picked up during regular collections. We have referred to such a system as a capacity-based fee. Service from the city is mandatory for all residents. The basic service is offered once per week with special collections, for an additional fee, available upon request. As we have discussed above, such a fee system may induce residents to dispose of less waste by imposing an additional fee. In addition, it may induce additional use of illegal disposal methods.

Unfortunately, the data in Sacramento are not detailed enough for us to make a definitive statement about these hypotheses. While good data on the amounts of waste disposed over time are available, other important data items, such as the number of containers chosen, are not.

An important difference in the Sacramento system is the provision for the pickup of lawn and garden refuse. Lawn and garden refuse in Sacramento is not collected by refuse crews. Residents are not required to place their garden waste in containers (except those in areas without curbs) but are required to pile the waste in the street no sooner than one day prior to the scheduled pickup. Thus all references to the solid waste system in this section exclude lawn and garden trash.

The basic equation estimated was:

$$Q = ap^b y^c s^d$$

Taking logs on both sides gives:

$$\ln(Q) = \ln(a) + b\ln(p) + c\ln(y) + d\ln(s) \qquad (27)$$

Again, as with Burbank, we will use dummy variables to represent three of the four seasons. Further, a surrogate is required again for the income variable. We again will use retail sales in the City of Sacramento. The basic one-can fee is not subtracted since it is small relative to income and no true income variable is available.

Using the data described above, the following results were obtained after applying OLS to equation (27) (again standard errors are in parentheses):

$$Q = 4.7 + \underset{(.07)}{.09} \ln(RS) + \underset{(.09)}{.23} \ln(p) + \underset{(.01)}{.01} \text{ WINTER}$$

$$- \underset{(.02)}{.01} \text{ SPRING} - \underset{(.01)}{.02} \text{ SUMMER} \qquad (28)$$

$$R^2 = .40$$
$$N = 26$$

There are three important results to note. First, the income elasticity, while positive, is insignificantly different from zero. Second, the price elasticity is positive -- and significant. Third, the seasonal dummies are not significant.

Because the existence of a positive price elasticity is theoretically implausible, the results in equation (28) were analyzed further. The first step is to recognize that, as with Burbank, the effect of income and price changes may occur only after some lag. The effect of lagging retail sales and incremental price by one period is:

$$Q = 3.6 + \underset{(.08)}{.20} \ln(RS) + \underset{(.10)}{.22} \ln(p) + \underset{(.01)}{.01} \text{ WINTER}$$

$$+ \underset{(.02)}{.02} \text{ SPRING} - \underset{(.01)}{.01} \text{ SUMMER} \qquad (29)$$

$$R^2 = .50$$
$$N = 22$$

Performing this regression results in a positive and significant income elasticity of .20. However, the problem of a positive and significant price elasticity remains.

Because the price variable used is deflated by the CPI and, for several months, the nominal fee is unchanged, the effect is that the incremental fee may be acting as a trend variable. To check this possibility, we substitute a trend variable for the seasonal dummies. When this is done, the results are:

$$\ln(Q) = 1.95 + \underset{(.12)}{.35} \ln(RS) + \underset{(.09)}{.09} \ln(p) - \underset{(.001)}{.002T}$$

$$R = .48 \qquad (30)$$
$$N = 22$$

The effect of this substitution is to retain the positive, and significant income elasticity (although the magnitude of the elasticity has increased to

.35). While the price elasticity is again positive, it is insignificantly different from zero. Further, while the R^2 is about the same as before, there are variables making the regression significant at a higher level.

Provo, Utah

Among cities with user fees for household solid waste collection, relatively few employ a variable fee structure based exclusively on pickup location, charging one rate for backyard service and another rate for curbside service. Provo, Utah, is one such city. Residents of Provo may choose between paying $2.50 per month for curbside collection and paying $5.00 per month for backyard collection.

Above, a demand model for a service-based fee was presented. In that model, the amount of waste generated was seen to be affected by the price of the service through the effect of service levels on waste generation. Unfortunately, the lack of data in Provo makes it impossible to estimate the demand specifications presented.

Other data that is available provides an opportunity to indirectly test for an income effect in the demand for increased service levels. This data is the breakdown by billing tracts of the percentage of residents choosing backyard service. While these tracts do not correspond to Census Tracts, they can be identified in terms of "housing value" which might be taken as an (albeit imperfect) surrogate for income.

We specify, therefore, the following equation:

$$BY = a_0 P^{a_1} + a_2 TRACT_1 + a_3 TRACT_2 + a_4 TRACT_3 \qquad (31)$$

where BY is the fraction of residents choosing backyard service, P^{a_1} is the price of backyard service, and the $TRACT_i$ are dummy variables representing the different areas of the city. There are 57 observations for each of the years 1975 and 1977. These represent years before and after the fee.

Applying ordinary least squares to (31), we obtain:

$$BY = -5.14 + \underset{(.13)}{.13P} + \underset{(.33)}{2.7TRACT_1} + \underset{(.32)}{1.7TRACT_2} + \underset{(.33)}{.82TRACT_3}$$

$$R^2 = .43$$
$$N = 114$$

We see that backyard service in each of the tracts, which are in declining order of housing value, is significantly and positively related to P. Note, also, that both the magnitude and significance of the estimated coefficients decline with TRACT number.

These findings in Provo lend some support to the existing evidence of positive income elasticities for solid waste services. However, because of the nature of the data, the support is not strong.

Grand Rapids, Michigan

Grand Rapids, Michigan operates a non-mandatory solid waste collection service which participating households pay for by purchasing plastic bags or tag cards whose price includes payment for municipal collection and disposal. Specially marked city garbage bags are sold for \$2.30 per dozen; tags are sold for \$1.25 for 10. The city also sells special plastic trash cans whose contents are collected upon payment of an annual fee of \$4.35 or \$6.50 depending on the container size. In addition, several privately owned collection firms operate in Grand Rapids, and residential households may arrange service with these rather than pay for municipal service.

A metered-bag system might be expected to affect residential solid waste behavior in two ways that are different from capacity based systems. First, the capacity of the bag is generally less than that of a waste can. Therefore, a metered-bag system faces the resident with a smaller increment of waste allowed between addition of a new bag. Second, because the bag is consumed when filled, the resident faces a direct charge for each additional bag used. With a capacity based system, once the number of containers is selected, there is no direct charge to the customer for using the number of cans chosen. Thus, the metered bag appears to fall in between the "ideal" system outlined above and a capacity-based system such as that in Sacramento.

This hybrid nature of the metered bag system makes the modeling of consumer demand for waste collection services somewhat more tricky than that of the capacity-based system. Fortunately, it turns out that it is possible with a single equation model to estimate the effect of price on waste generation whether the bag system is considered to be more like the "ideal" system with a charge varying with weight or more like the capacity system with the unit of capacity being the bag rather than the can.

Recall that with an ideal system, the resident is charged for the weight presented for collection each collection period. If the metered-bag system were a reasonably good approximation of the ideal system, the resident would not be able to "hide" additional waste by filling each bag with more waste. Therefore, the ratio of bags to waste would be constant and the "price per pound" could be calculated as:

$$p = p_{BAG}/(q/BAGS) \qquad (32)$$

where p is the price per pound, p_{BAG} is the price per bag, q is the weight of the waste presented for collection, and BAGS is the number of bags used.

If a double log specification is assumed for the waste generation function, it would look like:

$$q = a_0 p^{a_1} y^{a_2} s^{a_3} \tag{33}$$

where s represents seasonal factors, y is income, and q and p are as before. Substituting (32) into (33) gives:

$$q = a_0 p_{BAG}^{a_1} (q/BAGS)^{-a_1} y^{-a_2} s^{-a_3} \tag{34}$$

If the assumption concerning the constancy of the waste to bags ratio is correct, we can rewrite (34) as:

$$q = a_0^1 p_{BAG}^{a_1} y^{a_2} s^{a_3} \tag{35}$$

where:

$$a_0^1 = a\,(q/BAGS)^{-a_1}$$

Thus, we needn't make use of the data we have on the number of bags sold in Grand Rapids. This is fortunate since the data available are on wholesale sales and, therefore, incorporate inventory phenomena not on the part of the household but on the part of the retail outlets.

Suppose that instead of being viewed as an ideal system, the metered-bag system were merely another capacity based system with a different representation of capacity. Then, from the discussion in above, the theoretical representation of the demand model would be (assuming again a double-log specification):

$$q = b_0\,BAGS^{b_1} y^{b_2} s^{b_3} \tag{36}$$

$$BAGS = c_0 p_{BACT}^{c_1} y^{c_2} q^{c_3} \tag{37}$$

where the variables are defined as above. Substituting (37) into (36) and simplifying gives:

$$q = b_0 p_{BAG}^{b'_1} y^{b'_2} s^{b'_3} \tag{38}$$

Note that the specification in (38) is the same as that in (35). Therefore, estimation of either equation provides information about both possibilities. The difference is that if the metered bag system is actually a capacity based system, then the coefficients estimated for (38) no longer represent elasticities of price and income. Given some reasonable restrictions on the elasticities in (36) and (37), however, we can determine the sign on the price and income terms if the actual elasticities are to be negative and positive, respectively.

For example, if it is assumed that:

$$o > b_1 > -1, \quad 1 + a_1(1 + b_3) > o, \quad |a_1 b_2| < a_2$$

then the signs on b_1' and b_2' would be as expected from the economic theory. Note, however, that the numerical estimates of b_1' and b_2' in (38) cannot be construed as elasticities since they are complicated functions of other parameters and are not identifiable.

In order to estimate Equation (35) [or equivalently, Equation (38)], we must first transform it into the linear form:

$$\ln(q) = \ln(b_0') + b_1' \ln(p_{BAG}) + b_2' \ln(y) + b_3' s \qquad (39)$$

The next step is to identify the actual data series used in the estimation. For total waste disposed, the series presented above was employed. Because some of the data is expressed in cubic yards and some in tons, it was necessary to make the two comparable. To do this, we used the formula:

TONS = .29 YARDS

The factor of .29 is based on experience from Grand Rapids. For the "price of bags," we use the price of a bag. For the period during which bags were not available and tags were used, we use the implicit price of a bag based on the price of a tag. Therefore, when bags were not available but tags were and they cost $.10, we use .167 as the price of a bag.

For income, a better substitute was available in Grand Rapids than in any of the other cities. Grand Rapids has a city income tax whose rate has not changed over the period estimated. Therefore, we use quarterly observations on income tax collections as the surrogate for personal income with the quarterly observation being used in all three months.

For the seasonal variable, we use a dummy variable for Spring. This dummy serves two purposes. First, there is a high generation point in the months of May and June. Second, personal income tax collections peak in

April with the filing of returns. Both of these factors are held constant by the use of the Spring dummy.

Applying ordinary least squares to (39) gives the following result:

$$\ln(q) = 7.1 - \underset{(.46)}{.33}\ln(p_{BAG}) + \underset{(.25)}{.02}\ln(y) + \underset{(.10)}{.14}SPR \qquad (40)$$

$$R^2 = .08$$
$$N = 50$$

As we can see, the coefficients on price and income have the expected signs but are insignificantly different from zero.

It is unlikely, however, that the effect of price or income changes are felt immediately. If a distributed lag model is specified and estimated the results are (standard errors in parentheses):

$$\ln(q) = 5.4 - \underset{(.89)}{1.21}\ln(p_{BAG}) + \underset{(1.12)}{.50}\ln(p_{BAG-1}) + .29\ln(p_{BAG-2})$$

$$- \underset{(.37)}{.009}\ln(y) - \underset{(.42)}{.43}\ln(y)_{-1} + \underset{(.31)}{.70}\ln(y)_{-2} + \underset{(.11)}{.23}s$$

$$R^2 = .20 \qquad (41)$$
$$N = 46$$

None of the coefficients on price are significant and only the second lagged income term is significant (and of the proper sign).

The positive price elasticities are somewhat troubling even though they are insignificant. We, therefore, next specified and estimated the model:

$$\ln(q) = 4.4 - \underset{(.49)}{.50}\ln(p_{BAG}) + \underset{(.21)}{.40}\ln(y)_{-2} + \underset{(.09)}{.17}SPR$$

$$R^2 = .15 \qquad (42)$$
$$N = 46$$

The signs of the coefficients are all as expected. The coefficients on both the price and income terms are insignificant at the 95% level.

Tacoma, Washington

Tacoma, Washington has some fifty years' experience in financing solid waste collection and disposal through user fees. Over the years the city has considered or experimented with most of the various fee systems in current use around the country. The present fee structure is a combination of a capacity-based system and a location- or service-based system. Hence, it provides an example of the effects of combining several fee structures.

Residential households living in single unit or duplex structures receive mandatory weekly collection at a rate determined by the number of containers presented for collection and the level of carryout service provided. Households presenting refuse within 25 feet of a legal collection point (usually curbside, but alleys in some districts) are charged $2.45 per month for the first can and $1.15 per month for each additional can. Those presenting refuse between 25 and 75 feet from collection points are charged $3.90 for the first can and $2.65 for each subsequent can. Between 75 and 200 feet, and over 200 feet, the base prices are $5.30 and $6.65 and marginal prices are $4.05 and $5.45, respectively. A charge of $1.60 times the number of cans is levied for each flight of up to six stairs between points of collection and presentation. These are monthly fees paid along with electricity, water, and sewage bills on a monthly or bi-monthly basis. In addition, occasional extra bags of refuse left alongside regular cans are collected for a charge of $.75 each. Residents are required to pay for the minimum service of one can at less than 25 feet; about 30% of residential customers demand some level of optional service, a proportion that has steadily increased historically. Records from 1947 and 1958 indicate that in those years about 92% of all households received the minimum level of service; in recent years the figure has been about 75%. Households living in structures of three or more units are charged jointly for service at commercial rates. Finally, Tacoma residents may haul extra refuse to the city landfill and dispose of it at no charge; about 40% of all household refuse by weight is disposed in this way.

The first step in estimating the model for a combination structure presented above is to express each of the equations in a linear form. This results in:

$$\ln(q) = \ln a_0 + a_1 \ln C + a_2 \ln S + a_3 \ln y + a_4 \ln Z$$

$$\ln(C) = \ln b_0 + b_1 \ln p + b_2 \ln S + b_3 \ln y$$

$$\ln(S) = \ln d_0 + d_1 \ln p + d_2 \ln C + d_3 \ln y$$

For income, sales tax receipts were used. The seasonal variable used is precipitation (primarily because rainfall is relatively great in Western Washington).

For the variables q, C, and S, we have used the detail available in terms of the numbers of households selecting a particular service. Therefore, the monthly quantity variable is in terms of tons per household. For measures of the number of cans chosen and service level selected, we use the "odds" of choosing more than the basic level offered. That is, for cans, we use the odds of choosing more than one can of service which is the ratio of the number of households choosing two or more cans of service to the number choosing one can. Similarly for location, we use the ratio of the number of households choosing more than "curb" service to the number choosing the basic curbside service.

Using two-stage least squares, the resulting estimates are:

$$\ln(q) = -5.5 + \underset{(.93)}{.85} \ln C - \underset{(.77)}{.34} \ln S + \underset{(.22)}{.23} \ln y - \underset{(.003)}{.0002}\ \mathrm{PRECIP}$$

$$\ln(C) = 3.2 - \underset{(.11)}{.12} \ln p - \underset{(.13)}{.06} \ln y + \underset{(.42)}{.41} \ln(q) + \underset{(.12)}{.61} \ln S$$

$$\ln(S) = -5.9 + \underset{(.15)}{.09} \ln p + \underset{(.41)}{1.76} \ln C + \underset{(.30)}{.13} \ln y - \underset{(.97)}{.87} \ln y$$

As can be seen, the only significant explanatory variables are between the levels of service chosen.

Since precipitation was not significant and because the dummy variable representing the winter months appears to be important in many of the other case studies, we next substitute the dummy variable for winter for the precipitation variable. In addition, we add to the waste generation equation the variables for the number of extra bags (EXT) and the amount of waste self-hauled (SELF). The results, again applying two-stage least squares, are:

$$\begin{aligned}\ln(q) = -2.88 &+ \underset{(.86)}{1.0} \ln C - \underset{(.76)}{.42} \ln(S) - \underset{(.21)}{.02} \ln y - \underset{(.04)}{.08}\ \mathrm{WINTER} \\ &+ \underset{(5.3 \times 10^{-6})}{2.7 \times 10^{-6}}\ \mathrm{EXT} + \underset{(1.3) \times 10^{-8}}{9.9 \times 10^{-9}}\ \mathrm{SELF} \qquad R^2 = .36 \qquad (43)\end{aligned}$$

$$\ln(C) = 2.3 - \underset{(.05)}{.18} \ln p - \underset{(.06)}{.004} \ln(y) + \underset{(.08)}{.08} \ln(q) + \underset{(.05)}{.72} \ln(S)$$

$$R^2 = .92 \qquad (44)$$

$$\ln(S) = -3.1 + \underset{(.06)}{.15}\ \ln(p\ ) - \underset{(.10)}{.0002}\ \ln(y) - \underset{(.13)}{.14}\ \ln(q) + \underset{(.13)}{1.5}\ \ln(C)$$

$$R^2 = .88 \qquad (45)$$

The results of these regressions are interesting. Looking at equation (44) we see that there is a negative and significant price elasticity of .18. That is, for every 10% increase in incremental can price, the percentage of households choosing more than one can of service falls by 1.8%. However, from Equation (43) it appears that waste generation per household is not significantly related to the percentage of households choosing more than one can of service. If true, this would suggest that the way people respond to increases in the incremental price of containers is by demanding fewer containers and using those demanded more intensively. The price elasticity for location is, however positive and significant.

A second approach to testing for the existence of negative and statistically significant price elasticities is to derive the reduced form equation for waste collected and to use OLS. The reduced form (excluding SELF and EXT) can be shown to be:

$$q = a_0'\ p_L^{a_1'}\ p_c^{a_2'}\ y^{a_3'}\ \text{WINTER}^{a_4'} \qquad (46)$$

When OLS is applied to the logs of (46), the result is:

$$\ln(q) = -2.3 - \underset{(.26)}{.47}\ \ln p_L + \underset{(.49)}{.59}\ \ln p_c + \underset{(.18)}{.01}\ \ln y - \underset{(.03)}{.10}\ \text{WINTER}$$

$$R^2 = .43$$
$$N = 41$$

Neither of the coefficients on the price of an incremental can nor on location is significant at the .95 level.

Because the prices on containers and location are set by the same authority and change at the same time, it might be suspected that the coefficient estimates are inefficient (but not biased) because of mulitcollinearity. However, the two terms are not perfectly correlated. To regress quantity disposed on one of the prices (either container or location) would result in specification error. Further, because the exact form of specification error would be one of omitted variables and the omitted variable would be positively related to the included variable(s). Therefore, the coefficient estimated for the included variable would be biased away from zero.

CONCLUSIONS

The empirical results from the study are somewhat mixed. Income elasticities consistent with those found in previous studies have been estimated for Burbank and Sacramento and additional, but indirect, evidence of an income effect on service level was found in Provo, Utah. Insignificant income elasticities were estimated in Grand Rapids and Tacoma.

With respect to price elasticities, the only indication of significant coefficients is from Tacoma. This finding is, however, complicated by the fact that there are two price elasticities of interest, one on incremental containers and one on location. The finding of a positive price elasticity for container price suggests that some type of specification error might be the cause.

Additional, and indirect, evidence concerning price elasticities comes from attempts to examine the effect of user charge on illicit disposal methods. With data from the waste deposited in city parks (or other surrogates) we regressed quantity of "litter" on user fee. For no city was a significant relationship found. This finding is consistent with a finding of no significant price elasticity.

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EVALUATING THE EFFICIENCY OF THE SOLID WASTE CHARGE

by

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INTRODUCTION

The national Solid Waste Charge (SWC) policy has received considerable attention from the EPA over the past few years. The proposal is now being evaluated by the Resource Conservation Committee, and one specific legislative version has been introduced by Senator Hart. There is good reason for interest on the part of policy makers because the potential advantages of the SWC are quite striking, particularly in comparison to some of the alternative policies.

It is simple enough to state the logic or rationale of the SWC. The charge would act as an excise tax on that component of products entering the municipal waste stream. The amount of the tax would reflect the associated costs of collection and disposal, causing producers and consumers to reckon with those costs as they are incurred. So, the charge could, in theory, correct resource allocation relative to the present situation in which incremental waste contributions are non-priced and waste flows and materials consumption are correspondingly excessive. In addition, the charge would further reduce waste flows and virgin materials consumption by incorporating a recycling incentive in the form of exemption (in whole or part) of the recycled content of the taxed products. Since the charge would, in most cases, be levied on producers who purchase secondary and virgin inputs, the exemption would encourage increased secondary materials use. In most versions of the policy, the charge revenues would be distributed back to municipalities to fund solid waste management. In that case they would effectively reduce local property taxes. However, they could be channeled into other public goods or used to reduce personal income taxation, as well.

Thus, potentially, a solid waste charge can confer benefits both by: 1) improving the efficiency of public finance or pricing of waste management, and 2) by reducing rates of environmental spoilage and natural resource consumption. The first objective (which we call "PF") can be quantified in terms of the resource misallocation or "excess burden" of various taxes which could be used to finance the needed services. The second objective, conservation of environment and productive resource stocks ("CE") is much more difficult to evaluate, as everyone is aware. PF and CE are not entirely disparate since because of existing market failures we are creating too much solid waste--to the detriment of CE. An efficient level of solid waste flow, even measured in purely market values, would improve CE.

Now we have reached the point of departure for this paper--namely the "efficiency" of the SWC. The first thing we can say is that if the charge policy aims at two different objectives there can be no unambiguous measure or index of efficiency, particularly when one of the objective functions ("CE") has mostly subjective variables for its domain. Second, we must recognize that the SWC proposal includes a range of design options and that the problem of optimizing the design of the charge is itself endogenous to assessing its effciency with reference to either of the stated objectives. The major variables in the charge design are: 1) the level(s) of the charge(s); 2) the relative size of exemptions for secondary materials; 3) the points at which charges and exemptions are assessed; and 4) the use of the resulting revenues.

Two approaches to evaluating the efficiency of the solid waste charge will be described here. The first approach is based on a narow view of the range of policy concerns: that the charge is intended only to internalize the attributable costs of collection and disposal in the unit price of products. "Attributable costs" here means some estimate of short or long-run marginal cost, leaving aside the social cost concerns reflected in CE.

Using consumer and producer surplus changes resulting from the direct burden of the charge and adding the cost savings brought about by a smaller total waste flow a lower bound for potential net benefit of the swc can be found. Then the approximate sensitivity of net benefits to certain unavoidable sources of error in the level of the charge is analyzed. On the basis of current (but still relatively crude) empirical estimates of the variables involved, we conclude that the SWC is not at all likely to be an efficient means of internalizing (a narrow measure of) solid waste management costs.

The second approach to efficiency described here acknowledges the second best nature of all the policy proposals, including the status quo. Thus the disadvantages in terms of resource misallocation, equity and the other environmental and conservation dimensions inherent in the status quo of public finance of solid waste management and of materials production incentives would be accommodated. Enlargening the basis of comparability in this way would clearly allow a more comprehensive statement of the social opportunity costs of the various policy alternatives. However, this approach is limited by our ability to determine the social costs of the status quo and by the prevalence of subjective variables. In addition, a number of difficult-to-access empirical quantities come into this larger picture--such as long-run elasticities of supply of secondary materials, responsiveness of industry to charges in relative prices or to subsidies, the impact of environmental standards on long-run disposal costs and many others.

Here we do not attempt a comprehensive analysis of the various policies, their possible interactions and their probable effectiveness in forwarding the two objectives we have mentioned. Rather we identify some considerations bearing on such an analysis which would tend to improve our initial assessment of the solid waste charge. In light of those considerations--particularly those relating to the infirmities of the status quo policy--it seems that the SWC could possibly be part of a superior policy prescription. Some more study would be necessary to confirm or deny that proposition.

PERFORMANCE OF THE SWC AS A PRICING INSTRUMENT

Here we develop a lower bound measure for the potential net benefits conferred by an ideal SWC without a recycling exception. This amounts to a worst case assumption in that producers do not respond to the recycling incentive nor take steps to reduce the overall waste content of their products, but simply pass the charge through. The purpose of the following analysis is to establish an acceptable measure of the sensitivity of net benefits to error in the charge level; then we can make some rough estimates of how well the actual charge is likely to perform given that there are significant sources of error in the charge level. The main sources are: 1) substantial variation among municipalities in solid waste management costs; 2) ambiguity in allocating solid waste management costs among waste components; and 3) error in estimating a national average marginal cost, thus creating bias in the charge level.

Net Benefits of a Solid Waste Charge

To begin with, the net welfare benefit of the solid waste disposal charge can be analyzed as the algebraic sum of several components of welfare change. Initially we will assume a homogeneous waste stream, having geographically uniform and exactly measurable per unit marginal costs of collection and disposal. Thus, the level of the national solid waste charge corresponds precisely to the real resource savings associated with disposing of one less unit of post-consumer waste. For the time being, long and short run marginal solid waste management costs are assumed to be constant. The implications of large incremental costs incurred in switching to a new disposal site will be discussed later. We are considering, then, an ideal charge, which perfectly internalizes the relevant costs.

The solid waste charge will raise prices of the waste component of final products in accordance with the associated solid waste management costs. Unless demand for the product is perfectly inelastic or if the supply curve is a horizontal line (reflecting constant costs) the new quantity of product traded will be less than the original quantity and the new price will be greater than the original by an amount less than the per-unit solid waste charge. The increased price and reduced quantity imply a reduction in welfare for consumers and, in general, for producers of goods bearing the charge--that is, a loss in producers' and consumers' surplus. Part of the loss in producers' and consumers' surplus is regained by society in the form of the charge revenues. Additionally, solid waste management resources are saved by the reduced waste load corresponding to the lower quantities of waste-producing goods consumed. That resource savings represents a social gain. Finally, the amount of solid waste management services demanded may be further reduced by increased recycling, if the charge scheme includes an exemption for recycled materials. Recycling would lessen municipal waste management costs to the extent that secondary materials are diverted from the collection and/or disposal stages.

Clearly, the resultant net welfare changes should be positive after correctly internalizing waste management costs. However, the costs of administering the charge and of disbursing the revenues must be subtracted from the total net benefit. For the time being we will assume that these costs are a positive function of the charge revenues, denoted a(R).

Now we can state the elements of net welfare change in the following general expression:

$$\Delta W = -(CS + PS) + WR + SR + R - a(R) \tag{1}$$

where

CS, PS	are the losses in consumers' and producers' surplus, respectively,
SR, SR	are the solid waste management cost savings attributable to reduced quantities of post-consumer product waste and increased usage of secondary materials, respectively, and
R, a(R)	are the charge revenues and administrative costs, respectively.

It should be noted that some actual use must be made of the charge revenues, if they are to be reckoned as a benefit. The funds could not produce benefit if they were, for example, placed in escrow indefinitely, except for the possibly salutory effects of reducing the velocity of money. In fact, they should be applied to the margins of social or private expenditure prevailing at the new relative prices induced by the charge.

Lower Bound of Potential Net Benefits

It would be useful to determine what level of potential benefit an ideal solid waste charge would yield. The analysis is restricted to "potential" benefits because the administrative costs will be left aside. Other work has been, and will be done to assess the size of administrative costs. Also, we will initially ignore the savings in solid waste management costs arising from increased secondary materials use. In other words, firms pass the entire amount of the charge forward as increased product prices. These assumptions characterize a lower bound for potential net benefit of an ideal charge policy, since the recycling benefits are not included.

The expression for lower bound of potential net welfare charge, as just defined, is the following:

$$\Delta W = -\,(CS + PS) + WR + R \qquad (2)$$

It should be noted that the values of each of the right-hand-side terms in equation (2) would in general be different from the corresponding terms of equation (1). This is true because the price quantity equilibrium in the case of (2) is predicated on all of the solid waste charge being shifted forward, whereas equation (1) includes recycling effects, which would reduce foward shifting.

The potential lower bound of net welfare benefit can now be found. Denote the per unit charge level by t. Then the charge causes the final product supply curve to shift vertically, by the distance t in Figure 1, from s to s . The resulting surplus loss is represented by the rectangle p ade plus the "deadweight loss" triangle acd. The consumers' surplus loss is the area above the old price line, pcb, and the producers' loss is that below the old price line. The area of rectangle p ade equals t.q , which is also equal to the total revenues yielded by the charge. Therefore, those components of total welfare change "net out" as a transfer payment. The remaining terms, then, are the waste reduction effect and the deadweight triangle, acd.

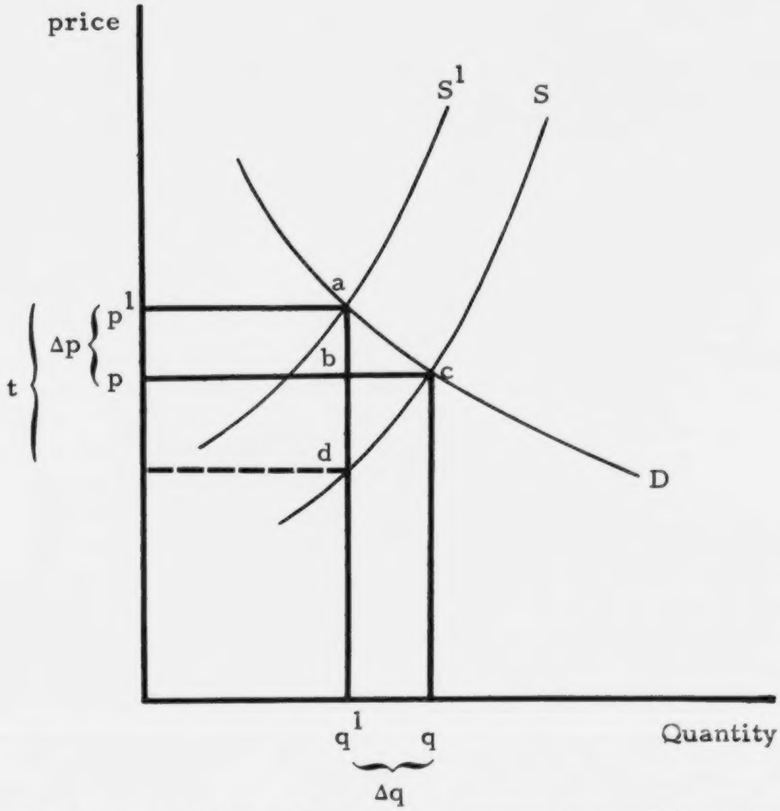

Figure 1. Effects of an excise tax on the solid waste component of products.

Since the per unit charge, t, accurately measures the per unit savings in waste management costs, those savings amount to t. q. That benefit is offset by the deadweight loss which is equal to (t. q)/2. To see this, note that the area of the deadweight loss triangle acd can be found as

$$\begin{aligned} acd &= acb + bcd \\ &= \Delta p\Delta q/2 + (t - \Delta p)\Delta q/2 \\ &= t\Delta q/2 \end{aligned}$$

Here it is assumed that the demand and supply curve segments, ac and dc, are linear. Given the small relative price change brought about by the charge, this assumption should give rise to virtually no error.

Summarizing these results in the form of equation (2), the net welfare change, under the assumptions detailed above, can be expressed as

$$\begin{aligned} \Delta W &= - (tq_1 + t\Delta q/2) + t\Delta q + tq_1 \\ &= t\Delta q/2 \end{aligned} \qquad (3)$$

This holds true irrespective of the elasticities of demand and supply, or if the good is supplied under conditions of constant costs. The elasticities do, of course, enter in determining the size of Δq, however.

Therefore, a lower bound of potential net benefit of the solid waste charge may be calculated as the per unit charge times one half of the reduction in quantity consumed. For example, if a solid waste charge of 3 cents per container were passed through entirely by the container manufacturer, and the resulting decrease in annual quantity traded were 300,000 units, then the potential annual net benefit of charging direct solid waste costs for those containers would be $4,500. It should be pointed out that the benefits of the solid waste charge rise in direct proportion to the size of the per-unit costs internalized. To the extent that the relative price of solid waste management continues to rise, the potential discounted future net benefits of the policy will also increase.

Sensitivity of Net Benefits to Error in the Charge Level

As has been mentioned, one prominent issue in the design of the solid waste charge concerns the preciseness of the charge level in reflecting actual solid waste management costs. Under somewhat limiting assumptions we will now examine the welfare losses that occur when the charge level and costs of waste management differ.

We will again assume a homogeneous solid waste stream, having per unit collection and disposal costs denoted by c. Also, we assume for the time being that the taxed product is supplied under constant cost conditions and that competition prevails. Thus the supply curve is a horizontal line. The per unit tax shifts the price up by the full amount, t, of the tax because the supply curve is horizontal. Because of error in the specification of the charge level, t and c are not equal. The expression for net welfare change becomes

$$\Delta W = -\,(tq_1 + 1/2t\Delta q(t)) + c\Delta q\ (t)\ +\ tq_1 \qquad (4)$$

$$= \frac{\Delta q(t)(2c - t)}{2}$$

The change in quantity traded depends on the charge level and so must be written as $\Delta q(t)$. Whent $t = c$, the welfare change is the maximal value, W^*, equal to $\Delta qc/2$ as before. Again assuming a constant elasticity of demand, ε , $\Delta q(t)$ can be computed as

$$\Delta q(t) = \frac{t}{p}\ q\varepsilon \qquad (5)$$

Let "a" denote a constant of proportionality between t and c, viz., $t = ac$. Then we may examine the sensitivity of ΔW to deviation between the charge level and waste management costs using the function $\Delta W(a)$.

$$\Delta W(a) = \frac{acq\varepsilon}{2p}\ (2c - ac) \qquad (6)$$

$$= (2c^2a - a^2c^2)\,\frac{q\varepsilon}{2p} \qquad (6a)$$

This function behaves as it should, having its maximum of ΔW^* $(=c^2q\varepsilon/2p)$ at $a = 1$, since

$$\frac{dW(a)}{da} = (2c^2 - 2ac^2)\,\frac{q\varepsilon}{2p}\ ;\text{ and} \qquad (7)$$

$$\frac{dW(a)}{da} = 0 \text{ only if } a = 1, \text{ for nonzero } c.$$

A second important and obvious characteristic of W(a) is that it is zero for $a = 2$ and negative for larger values. Similarly, for $a = 0$ W is zero, as we would expect. Thus, if the solid waste charge overstates the actual relevant costs by 100 percent then it results in no net benefit and actually reduces welfare if the overstatement exceeds 100 percent.

However, under the present assumptions, we find the net benefit calculus is quite forgiving of relatively small values of error. The relevant part of the parabolic function W(a) is graphed in Figure 2 (for =1) and pairwise values of W and charge error are set forth in Table 1. A 10 percent error in the charge level gives rise to only a one percent loss of lower bound potential welfare, and a 20 percent error corresponds to a loss of four percent. The rate of benefit dropoff increases more rapidly with greater deviation between the charge level and the relevant solid waste management costs. While a 25 percent error in the charge results in only a 6.2 percent loss of welfare, an additional 25 percent error leads to a loss in realized benefit of 25 percent, or a fourfold loss resulting from a twofold greater error. A third increment of 25 percent error—or 75 percent error—reduces benefits by about 56 percent.

TABLE 1. SENSITIVITY OF LOWER BOUND POTENTIAL NET BENEFIT TO ERROR IN THE CHARGE LEVEL FOR $\varepsilon = 1$

Value of a (=t/c)	Percent error in charge level $(\lvert t - c \rvert / c)100$	Percent of potential welfare lost $((\Delta W^* - W(a))/\Delta W^*)\ 100$
1.0	0	0
.9 or 1.1	10.0	1.0
.8 or 1.2	20.0	4.0
.75 or 1.25	25.0	6.2
.67 or 1.33	33.0	11.6
.5 or 1.5	50.0	25.0
.33 or 1.67	67.0	44.9
.25 or 1.75	75.0	56.2
.2 or 1.8	80.0	64.0
.1 or 1.9	90.0	81.0
0 or .2	100.0	100.0

For the present purpose we retain the assumption of unitary elasticity of demand, as a convenient approximation to the range of elasticities for products affected by the solid waste charge. It would not be difficult, in a more detailed analysis, to utilize the elasticity and consumption shares data for major product categories used by Research Triangle Institute in their economic model of the solid waste charge. The effect of higher elasticity is to increase the sensitivity of net benefits to error. In othe words, for products having price elasticities of demand in excess of one, the parabola in Figure 2 would be more steeply shouldered.

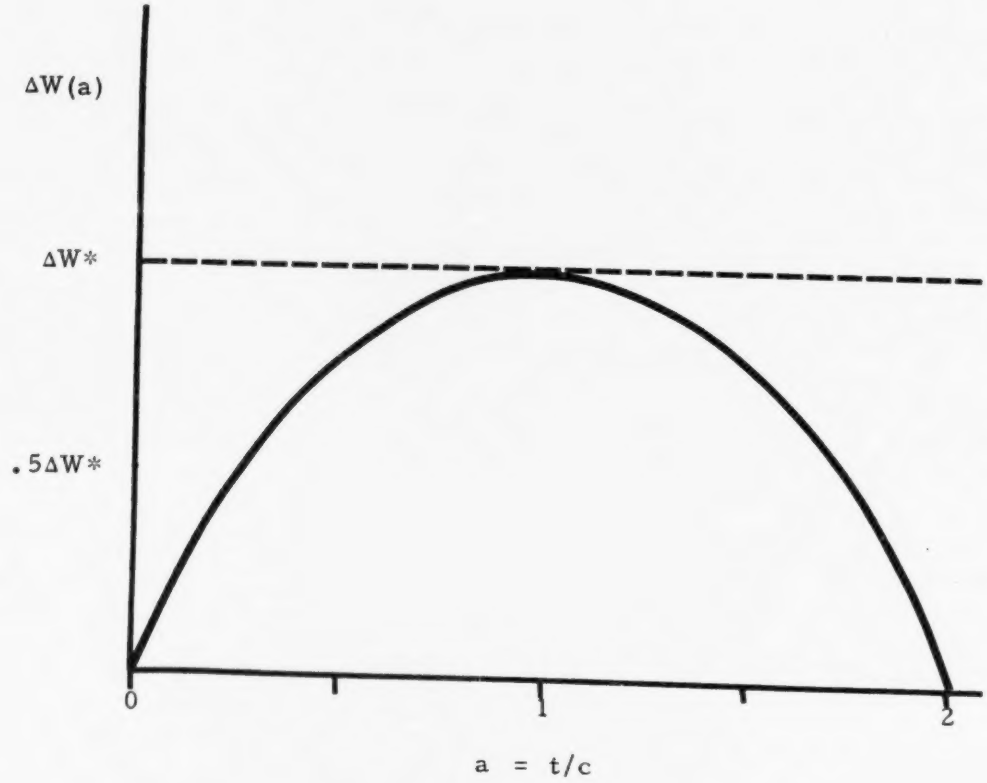

Figure 2. Lower bound of potential net benefit as a function of error in the charge level.

Applicability of the Analysis

Now it is appropriate to inquire whether the results just described have much relevance to estimating the net benefits of the charge under realistic conditions. Preliminaryily, we conclude that the method is applicable and useful as it stands, and can be readily refined further. The assumptions of constant elasticity and linearity of demand and supply functions, though contradictory, cannot contribute significant error except possibly in those few cases where the charge induces a very noticeable jump in product prices. Even then it is unlikely that these assumptions would give rise to error greater than that which would result in an attempt to estimate entire supply and demand schedules. Clearly there is no payoff in the kind of refinement.

The major assumption is that of the constant cost supply function. It seems reasonable that a great percentage of consumer products are in fact supplied under conditions approximating constant costs, particularly since we are considering aggregated national markets. Yet it would be useful to determine what happens to our analysis if that is not the case, and for certain segments of the market it will not be.

With a rising supply curve some of the tax burden will be borne by producers. That case, which is of course the general one, is depicted in Figure 1. There the tax wedge raises the consumer's price by p and reduces the suppliers' price by ep. Ultimately the producers' share of the tax would be shifted back to owners of those inputs having the lowest elasticities of supply employed in the industry, in the form of reduced rents.

However, producers also have the option of substituting away from the taxed dimension of the product, which in this case is essentially the packaging component of the product, or the virgin materials content of the packaging. There are two basic kinds of substitution possibilities which allow producers to reduce their tax burden:

- reducing the proportion of virgin materials at the basic materials level

- reducing the packaging component of the product, or at least the taxed dimensions of the packaging component.

For the most products these two possibilities occur at different stages of the production process, usually in different firms. But the observaton still holds, regardless of which stage of production is taxed, that producers having relatively strongly upward sloping supply functions have greater incentive to reduce the tax. This effect makes the lower bound measure of net benefit analyzed above more applicable to the upward sloping supply case, insofar as producers substitute away from the waste component as a whole. It makes no difference which side of the market brings about waste reduction effects in measuring the net benefit of the charge.

To the extent the proportion of recycled materials is increased in order to reduce the tax, our formulation understates the net benefit by leaving out the recycling benefits, viz., the term "SR" in equation (1). Yet the value of such benefits, incorporated in the level of the secondary materials exemption, is the expenditure of solid waste management expenditures avoided by recycling. This mode of substitution amounts to what is also basically a waste reduction effect.

Thus, on the whole, the lower bound method just described above should be a useful and acceptable approximation for policy analysis.

To the extent this analysis is actually representative of the net benefit behavior of the solid waste charge, the message is clear: the efficiency benefits of the policy disappear entirely if the degree of error in measuring the relevant costs and in implementing the charge is comparable to the size of the charge itself. It seems that this in fact is the case.

Assessing Net Benefit Losses

Source of Error in the Charge/Exemption Levels--

Several sources of error or bias in the level of a national solid waste charge can cause misstatement of the relevant costs which the charge is intended to internalize. They are:

- Differences among municipalities in the relevant costs of waste collection and disposal.
- The existence of local user fees which partly or wholly recover waste management costs in about 10 percent of local jurisdictions.
- Ambiguity in allocating solid waste costs among materials types and waste components.
- Determining the amount of the recycled materials exemption, based on estimates of the waste management costs avoided by increased secondary materials use.
- Determining the level of the charge based on estimates of the national average waste management costs imposed by increased disposal per household at the margin.

The first point above is probably the most significant, because interlocal solid waste management cost variability appears to be very substantial. So, the charge overstates or understates the relevant costs in accordance with the variance of observed costs, in effect creating a component of random error in the charge from the point of view of individual communities. We will concentrate on assessing the impact of the error component here, not only because it probably dominates other kinds of error or bias, but also because there is at least some of the needed empirical information available.

The existence of local user fees could create some significant bias in the charge/exemption levels. Local user fees combined with the SWC would create a situation of double-charging for waste collection in certain areas. It seems reasonable to expect that adjusting or discontinuing local user fees would be part of the start-up costs of the SWC, if, in fact, the charge revenues were to be redistributed to cover local solid waste costs. Otherwise, inhabitants of those areas would be systematically overcharged, relative to the rest of the nation. This would happen to the extent that local fees were more highly correlated with waste management costs per household than the property tax or other sources of funds relied upon elsewhere. Evidence suggests that that correlation is quite poor in the case of the property tax and noticeably imperfect in the case of user fees. We will not attempt to assess benefit losses from imposing charges in addition to local fees. The main points here are that evaluating those losses depends on the use of the charge revenues and on the second best nature of the alternatives, which we discuss in more detail later on.

The problem of allocating costs among waste materials components seems to be a rather severe one, even at first glance. First, those costs clearly depend on the weight and volume characteristics of waste components. However, even in a given jurisdiction, the weight/volume cost relationships can change if packer trucks have different compaction ratios, or if differing pickup (e.g., for apartments vs. houses) or disposal methods are used. Also, the weather can significantly alter the relative cost shares of waste components.

The volume/weight ratios of cardboard and newspaper change drastically when they become wet, thus creating daily and seasonal changes in cost shares. Finally, the compaction characteristics of any given item depend on the mix of waste surrounding it. For example, cans will compress relatively more when surrounded only by other cans than by corrugated boxes and plastic containers.

EPA has initiated a project with the National Bureau of Standards to measure compaction ratios of waste components in a "typical" mixed waste environment and to devise a cost allocation procedure, using representative assumptions on pickup, transport and disposal in a landfill. No results are available as yet, but obviously there will be some error in those cost estimates. Here we will simply make some hopefully reasonable assumptions about the size of that error in order to assess the resulting net benefit losses.

The final two points mentioned above, determination of the charge and exemption levels, entail both conceptual and empirical questions. The conceptual issues are the economic bases for the levels of the charge and exempion. The charge should reflect all costs attributable to the additional unit of household post-consumer waste. Those costs could be reckoned relatively narrowly or broadly as we discuss in Section III, below. At minimum, a more inclusive measure would also reflect costs of capacity expansion and environmental upgrading of landfills. The more inclusive cost bias notion would be more applicable in some areas than in others. Likewise, the exemption should reflect costs avoided by recycling. Those avoided costs may be collection costs, and/or disposal costs, depending on locality and type of material.

In addition to bias and errors arising from improper economic basis of the charge and exemption, some further inaccuracy will occur in estimating national average values of the cost components used in setting the charge/exempion levels. Some of the deficiencies of present best estimates of marginal collection and disposal costs are mentioned later. The estimates of exemption levels rely on the original cost estimates as well as on other empirial information which has not yet been adequately sampled or analyzed.

The lack of precision in determining national average charge and exemption values will lead to some degree of bias in the impact of the charge on economic incentives. Again, we must rely on guesswork in looking at the economic effects of that bias. Presumably, such effects would tend to abate if the charge were properly implemented, with some attention placed on improving data bases and empirical estimates.

Probable Magnitude of Benefit Loss--

As should be clear by now, the best we can do at present in assessing the efficiency of the SWC as a pricing instrument is to approximate a likely range of potential benefit loss resulting from the various sources of error. Ideally, we should treat each source of error as a stochastic variable with a known or estimated distribution, and the total effect should be computed as a sum of random variables. Also, the welfare loss estimates should be based on estimated elasticities of demand and supply for the particular markets affected. For this purpose however, the assumptions of competitive supply and unitary price elasticity of demand do not appear to be unreasonable. The consumption data used in the RTI model indicate a demand elasticity of .99 for the non-food, non-beverage segment of the market--which bears by far the greatest burden of the charge on paper and flexible packaging. Also, that market segment represents 75 percent of personal consumption expenditures. The major deviations from unitary demand elasticities occur in beverage, beer, wine and spirits categories comprising 2.7 percent of personal consumption expenditures. Demand elasticities range from .4 (beer) to 1.7 soft drinks to 2.2 (wine) in those markets. Canned foods, which could also be relatively strongly affected by the charge, exhibit low price elasticities (.17) and comprise 1.3 percent of household expenditures. The consumer surplus loss in inelastic demand markets would be relatively less sensitive to error in the charge level.

Now it remains to combine our scanty knowledge of the various sources of error and bias with the welfare loss function of Figure 2 and Table 1. The variance of local waste management costs can be assesed only rather indirectly. Data on average cost per ton (collection only) are available for 177 cities of greater than 2,500 population from the Columbia Survey. Table 2 shows the distribution of those costs in 1974 dollars. The national average collection cost in 1974 was $24.91/ton. Disposal costs averaged $4/ton bringing the 1974 average total cost per ton to $29. The distribution of disposal costs (as measured by fees charged to private sector collectors) also showed considerable dispersion according to EPA staff.

Assuming that the charge was set at $25/ton, the efficiency losses resulting from variation of local costs are shown in Table 2.

The overall efficiency of the SWC computed on this basis is 65 percent. In other words, only 65 percent of the welfare gains from properly internalizing waste management costs are realized. That figure neglects the sizable net losses that would occur in about 10 percent of the communities

TABLE 2. DISTRIBUTION OF AVERAGE PER TON COLLECTION COSTS AMONG MUNICIPALITIES AND CORRESPONDING SWC EFFICIENCY LOSSES

Cost class $/ton	Number in class	Percent in class	Deviation from charge level % of class median	SWC efficiency by class	Weighted efficiency (%)
0-10	19	10.7	233 (median = 7.5)		
10-15	29	16.4	100	0	
15-20	32	18.0	43	.84	15.12
20-25	34	19.2	11	.98	18.81
25-30	15	8.5	9	.98	8.82
30-35	14	7.9	23	.93	7.35
35-40	12	6.8	33	.88	5.98
40-45	8	4.5	41	.84	3.78
45-50	5	2.8	47	.76	2.13
50-70	3	1.7	58	.65	1.11
70	6	3.4	66 (medium = 75)	.55	1.87
					65%

Based on national average collection costs of $25/ton, 1974 dollars.

where the cost are less than half the charge rate. More importantly, the estimate also is based on average costs, not marginal costs. Only if the distribution of average costs is similar to that of marginal costs does our 65 percent efficiency value have much significance. Engineering analysis of municipal waste production functions seems to be the only feasible way to determine whether the relevant marginal cost would have a broader distribution than average costs. I am inclined to think that is not the case, but if it is, then it appears that a big share of the potential benefit of the charge stands in jeopardy. It should also be noted that if the relevant cost distribution has a mode in the neighborhood of one-half the charge rate or less, then net losses occur for inhabitants of those communities. That could undermine the efficacy of the SWC policy considerably. The empirical data sample used here does not adequately represent major population centers, where costs are higher.

Assuming that local cost variation does result in approximately a 35 percent loss in net SWC benefits, it seems reasonable to expect that the other implementation problems--estimating precise central values for the charge/exempion level and allocating costs among waste components--could easily reduce the overall efficiency of the SWC to below 50 percent.

Some empirical work is necessary to guage the degree of error in assigning cost shares among various waste components. In one sense, it seems to be misleading to think that those shares are fundamentally well-defined. There is a problem akin to an index number problem in economics, in assigning those cost shares. Beyond that, there will always be some geographic variation in cost shares, owing differences in relative importance of collection, transport and disposal costs, differences in climate and differences in mix of waste, among other things. If error in assigning cost shares averaged 33 percent across all goods and communities, then the net benefit of the charge could be expected to decline an additional 11 percent. (It may be possible to minimize those losses if the cost shares of relatively elastically demanded goods, e.g., wine, soft drinks, prepared beverages could be determined relatively more precisely.)

Finally, if bias in the charge and exemption estimates yielded a further loss of 5 percent of the benefits, we would find that the SWC yielded only about half of its potential benefits. (Potential benefits here excludes waste reduction effects associated with increased recycling. Those effects do not figure importantly in the RTI estimates of total net benefit.) According to RTI's recent estimates of total net benefit, a reduction by one-half would place the net benefit of the charge in the range of \$13-\$30 million annually, depending on whether elasticities of supply of secondary materials are assumed to be relatively low or high, respectively. Subtracting \$10 million for estimated annual administrative costs, we find that the SWC appears likely to be a rather marginal policy alternative. It should be noted, though, that the RTI estimates are preliminary. Also, they are based on a \$30/ton charge rate, which probably comes much nearer to average cost pricing rather than marginal cost pricing.

Obviously, further work is necessary before we can assess either the efficiency or the net benefit of the charge as a pricing instrument with sufficient reliability to make a policy determination. However, if we consider the SWC as one of several second-best public finance instruments, then much further refinement of data and estimating procedures appears to be somewhat lower in priority.

THE SOLID WASTE CHARGE IN A SECOND-BEST SETTING

The previous discussion of the efficiency of the SWC purely as a pricing or public finance instrument assumes that there are no pre-existing distortions elsewhere in the economy. Otherwise the demand and supply curves central to the analysis do not fairly represent the opportunity costs associated with price and quantity movements. Because of the smallness of the SWC relative to prices of most of the affected goods, we are dealing with truly marginal changes, so our estimates of the efficiency performance of the charge are fairly robust. However, what of the distortions inherent in the *status quo* or in the other contemplated policy alternatives? We would not have formulated our two objectives at all if there were not pre-existing market failure in the waste sector. So, although the charges may in actuality yield little of its theoretical potential benefit or may even yield negative net benefits, the net benefits of the *status quo* and/or other alternatives may be worse yet. So, the less-than-ideal expected performance of the SWC must be matched against that of the other policies. Below we discuss several considerations arising out of the second-best approach which could conceivably place the SWC proposal in ascendancy, all things taken together.

We also discuss the level of charge. The potential net benefits increase with the size of the cost internalized in the charge but the usual marginal cost pricing logic combined with current econometric estimates of marginal cost may yield a charge level which falls substantially short of the optimal one. We take up this issue first.

Cost Basis of the SWC

Determining what the level of the SWC should be raises two obvious problems. First is the problem of deciding which elements of cost should be included in the charge. Even if we leave aside extramarket social cost (reflecting environmental and conservation objectives) the answer is not obvious. Having decided on a cost basis there is, then, the issue of reliably estimating the costs.

The studies now being conducted by the EPA rely on estimates of long-run marginal cost to set the charge level. There are several margins in municipal waste management cost functions. In collection the margins occur in providing service to an additional household, providing a higher level of service, and in picking up a greater quantity per household. Additionally, there are costs of transport, transfer and disposal which depend largely on the location of the disposal site and somewhat on route patterns. Finally, there are long-run costs of providing new disposal facilities. In the short-run the solid waste charge would impinge directly only on the quantity per household margin, and very slightly on transport and disposal.

Estimates of long-run marginal costs using the best available (Columbia University) data indicates a very low elasticity of cost with respect to quantity per household—certainly no greater than 15 percent of average per ton costs. These estimates are unreliable for several reasons:

- The sample of cities, while quite large enough, excludes cities of greater than 700,000 population, where the per capita costs would be highest. Also, towns of less than 2,500 were excluded.
- Costs of transfer stations and incineration are excluded.
- Disposal costs are measured by the disposal fees municipalities charge.

EPA is working to overcome these data deficiencies and to improve estimation procedures, but even then one would have to question the efficacy of econometric techniques in producing reliable estimates of the needed kind. The regressions produced so far show inconsistencies in signs of coefficients, spotty statistical significance and gross differences in results on a ton vs cubic yards measure of output. Given the sensitivity of net benefits of the SWC to the relevant cost level, it seems inadvisable to rely on econometric estimates of cost elasticities. Engineering-based estimates would surely be preferable in this instance.

Returning to the question of selecting the cost basis of the charge, it would seem the empirical estimates of long-run marginal costs could not capture some of the relevant costs associated with higher overall rates of disposal. The costs of acquiring new landfills and of operation with new disposal sites are reported to be increasing rapidly. Those costs must be incurred sooner without a SWC than otherwise (unless implementing user fees would reduce wasteloads more than the national charge). Perhaps more important, the costs of upgrading disposal sites to environmentally acceptable standards, which may be on the order of $3 ton per year, are not adequately reflected in the 1974 data. Some portion of both of these categories of incremental costs should be included in the solid waste charge level.

The next question concerns the other elements of cost mentioned above. Should some of those be included in the SWC, so that it approximates more nearly an average rather than a marginal cost change? This would amount to using the SWC as an additional taxation instrument to raise social overhead revenues associated with the fixed cost elements of waste management.

Optimal Taxation Considerations

Using the SWC as a means of raising social overhead implies the substitution of an excise tax for a property tax (and to a minor extent local income taxes). In that case, the charge could be used to recover all the cost components except those related to level of service which would probably be more efficiently and equitably recovered through a flat rate related to service level. An average cost recovery scheme would clearly result in a much higher charge level, (by factor of 3 to 6) than the presently contemplated marginal cost-based charge. It would create some excess burden effects, which must be compared to those of the existing property tax-based financing arrangements.

Research done to date indicates that the static, and especially the dynamic, efficiency losses associated with the SWC would be noticably less than those for the property tax. The horizontal equity of the SWC would clearly be greater, assuming that redistribution of revenues could be kept reasonably in line with local costs. The incidence of the property tax is undoubtedly more poorly correlated with household waste generation rates than the SWC. In fact, the solid waste charge may resemble the formulation for optimal commodity taxation which prescribe relative small, pervasive excises on commodities with relatively low price and income elasticity. Some additional research is needed to evaluate that resemblance further.

Offsetting Pre-Existing Distortions

Repeal of tax laws which lead to excessive rates of mining and harvest of productive resource stocks does not seem to be in the offing. The SWC probably could be used to offset those tax subsidies. Whether it would be an effective instrument for that purpose remains to be seen. Other policy alternatives which would have similar effects are subsidies to recycling firms and standards for recycled content. Those policies have other serious disadvantages, however.

Conservation of Environment and Productive Resources

The SWC may have some significant conservation advantages relative to other material policies and charging schemes. Since it is a direct tax on producers, it constitutes a direct incentive for them to substitute away from waste components of products and particularly virgin material components. Volume-related user fees may do this indirectly, but may also raise littering and unauthorized dumping, both of which are very costly not only in environmental but in fiscal terms. The SWC also directly induces consumers to substitute away from waste intensive products, which no other policy does. Finally, it encourages recycling in accordance with market demand through price incentives. One must be skeptical of lump sum handouts to budding industries in order to get them started. Commercial capital and entrepreneurship should become available when the market is created.

The advantages just mentioned may not be particularly great. Some imponderable notional values and quite difficult-to-estimate empirical factors are involved. However, whatever positive conservation and environmental effect could be ascribed to the SWC will certainly increase as the level of the charge increases. Here is another argument, then, for financing fixed-cost related municipal waste management overhead out of SWC revenues. That approach not only yields excess extra-market benefits, but also reduces the waste load and overall economic burden on households.

The intention here has not been to campaign for the SWC policy, but rather to describe two hopefully diagnostic points of view in analyzing the probable benefits of such a policy. Those benefits pertain to the public finance and conservation objectives implicit in the SWC proposal. The evaluation method favored by the RCC and followed in Section II above confronts only the PF objective. And it does that in an incomplete manner, by leaving aside the second-best nature of the other PF instruments. It seems that such an approach is definitely too narrow, given the stated concerns of the Resource Conservation Committee and of the EPA mandate, for that matter. Hopefully some of the lines of enquiry mentioned here can be followed further in order to produce a truer assessment of the various initiatives, relative to both the PF and CE objectives.

This argument gains force when the SWC and other policies, for that matter, are looked at in the longer view, rather than merely in terms of discounted net policy benefits for the next few years. Are incentives in the solid waste generation and management sector genuinely askew? Clearly the attendant environmental and productive resource allocation costs are rising, if not accellerating. At this point, I think debate should focus on how to restructure incentive patterns to create long-term corrective influences. Quite possibly no single proposal or mix of proposals could outweigh its distortional and administrative costs, but such a judgment cannot be supported without examining more thoroughly the disadvantages of the status quo, in terms of both the PF and CE perspectives, than we have as yet done.

ECONOMIC APPROACHES TO SOLID WASTE MANAGEMENT: EUROPEAN EXPERIENCE

by

W. DAVID CONN

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INTRODUCTION

This paper discusses the application in Western Europe of (i) continuously varying user charges for household solid waste services (that is, charges that vary for each collection according to the quantity of waste collected), and (ii) product charges (that is, solid waste-related charges levied on products at the time of manufacture or distribution). The discussion of user charges is based on research conducted between May - September, 1978, while the information on product charges was collected largely between November, 1976 - January, 1977 (with some subsequent up-dating).

USER CHARGES

Earlier Studies

A 1973 study by the French consulting firm CERU[1] compared the method of financing solid waste services then generally employed in France with those used in the U.K., Germany (Federal Republic), and Sweden. The French at that time typically paid for solid waste services via a tax collected at the same time as property taxes. The study identified a continuum of alternative approaches ranging from:

(i) the use of local general revenues (collected via property taxes, etc.), with no direct connection between the amount paid by an individual household and the cost actually incurred (as in the U.K.); through

(ii) the establishment of a charge that varies according to the size and number of containers regularly collected from each household (as in many parts of Germany); to

(iii) the establishment of a charge that discriminates more finely between households according not only to the size and number of containers but also to the distance from the storage area to the street, the distance between pick-ups, the frequency of collection, etc. (as in some metropolitan areas in Sweden).

The study pointed out that the use of general revenues may be justified on the grounds of providing a public service advantageous to all members of the community, as well as on the grounds of simplicity (there being no need to collect an extra tax or charge). On the other hand, the study also mentioned three major problems, resulting from the absence of a direct link between the payments made and the costs incurred, the likelihood of inadequate financing (due to competition for scarce funds in the municipal budget), and the lack of any incentive that can be used to encourage "good" solid waste practices on the part of households.

Solid waste charges were said to be based on two principles, namely that the total sum collected should cover the total cost of the service provided and that the contribution of each user should equal the cost of the service received by that user. The study argued that the use of charges gives flexibility in maximizing the efficiency of the service, and that it provides an incentive for households to cooperate (or be charged accordingly). A charging system can be made more or less elaborate, with varying costs of administration, accounting, etc.

The possibility of establishing charges that vary for each collection according to the quantity of waste collected was one variation of the charging approach considered in the report. The system could employ trash cans (or some other kind of reusable receptacles) or disposable bags.

Trash Can System

In its most complicated form, this would require the collection crew to make detailed estimates of the quantities of waste placed out for collection, which would then provide the basis for billing. The study rejected this method owing to the difficulties of estimating the quantities, of keeping a daily record, and of resolving queries. A simplification would be to base the charges just on the number of containers (irrespective of the quantities contained); another possibility, which would avoid the need for recordkeeping or billing, would be to levy the charge at the time of collection, e.g., using tokens attached to the containers. The study was unenthusiastic about these methods; instead, it presented the alternative of having households pay a regular subscription for the right to place out a pre-specified number of containers at each collection (the charges no longer varying on a day-to-day basis with the actual amount of waste collected).

Bag System

The study discussed the possibility of selling bags at a price that would include the costs of collection and disposal. The advantage would be the avoidance of record-keeping or billing, but several disadvantages were also identified; these included the fact that the method ignores differences in the costs of collecting and disposing of different bags (depending on their location, the number picked up at any one location, etc.), the problems of requiring users to go to buy the bags, and the incentives that users would have to dump waste improperly or to misuse the bags (e.g., by overfilling), creating difficulties for collection. The study concluded that this method has to be approached with caution.

A later (1976) study by the same firm examined solid waste financing options for the community of Beaune[2], a small but growing town (and center for the production of burgundy wines) in Cote d'Or, near Dijon. At the time of the study, the municipal service was collecting waste from a population of about 19,000. The existing system involved the use of bags that were distributed regularly (usually annually) by the collection service to all houses, apartment buildings, etc., the number of bags depending on the number of people resident. The system was financed by a tax which in 1974 covered only part of the cost incurred but which was increased the following year to cover the full cost. It was felt that the system was inequitable since the tax was the same for each household, while calculations showed that the cost varied significantly, depending on the number of people in the household.

The study proposed either that a charge should be levied depending on the number of people in the household, or that bags should be sold at a price covering the cost of the service. In connection with this second alternative, the study identified as problems the fact that arrangements would have to be made for selling the bags (and commercial firms might not wish to act, in effect, as revenue-collectors for the municipality) and the fact that the system might encourage improper dumping or the placing out of wastes without bags. On the other hand, the system would be equitable and would not require a register of households to be maintained. The study made no conclusive recommendation as to which system should be implemented.

In reality, the community decided against using the sale of bags as the means of charging for solid waste services, for fear that people would evade the charge by improper dumping[3]. Instead, the community is examining how a register of households might be established, so that charges can be based on the number of people living in a residence.

Actual Experience: Baden-Wurttemberg, Germany

A system of charging based on containers was introduced many years ago in a part of the Lande (State) of Baden-Wurttemberg, near the city of Stuttgart, on the grounds that it was an equitable means of pricing[4]. Users indicated that they had paid for the solid waste service by attaching tokens to each (standardized, 35 or 50 litre) container; they had the choice of purchasing either an annual "stamp" or individual "strips" for each collection (the strips being broken when the containers were emptied). The tokens were issued by the local authorities and sold by local banks, without any surcharge.

One problem was that the strips were sometimes mutilated or detached prior to the collection, e.g., by children. As a result, an attachment to the strips was introduced which could be removed by the householder and kept as proof that the charge had been paid. In practice, containers without strips were generally emptied anyway, especially when it was apparent that the strips had been improperly detached.

The prices charged for the tokens were re-calculated annually based on an estimate of likely expenditures on solid waste services for the coming year (including separate collection of bulky wastes, provided at no direct cost to householders) and an estimate of the number of stamps/strips expected to be sold. The stamp was sold at a slight discount compared to 52 strips.

The system was used in the cities of Leonberg, Fellbach, Waiblingen, Reutlingen, and Tuebingen but it was discontinued in all but a part (about one-quarter) of Waiblingen because of two problems, namely:[1]

(i) difficulties in estimating the weekly amount of waste collected, necessary for efficient planning of routes, vehicle capacities, etc.; and

(ii) considerable increases in the quantities of bulky waste and litter (although the quantities of household waste placed in the standardized containers decreased). Specifically, the frequency of removal of bulky waste had to be increased 2 times per year to 8-10 times per year, signifying an estimated increase in bulky waste volume of 400%-500%. Although the ratio of household to bulky waste generation is known to depend on the size of containers used for the household waste (the use of smaller containers typically causes an increase in bulky waste), it is reported that communities using the token system generated much more bulky waste than other comparable communities (using the same types and sizes of containers).

Overall, costs were found to increase. The proceeds from the sale of tokens were insufficient to cover the costs, and the difference had to be made up from other sources, e.g., general revenues. However, users generally liked the system and some applied (unsuccessfully) to the courts for its continuance.

It may be noted that a 1973/74 study[5] conducted in the district of Kurten in the county of Kreis (a rural/resort area) revealed that where residents were charged for the use of bags for household waste, the amount of waste collected from each household was approximately half by weight of that collected from an urban district with a normal container system; however, the amount received at the disposal site (including household, bulky, and commercial wastes) was about the same (roughly 350 kg per person per year).

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1. It has also been reported that the municipal finance officers did not like receiving revenue in 52 installments.

Netherlands

A new Wastes Act was passed in the Netherlands in 1977. The supporting text[6] mentioned that some communities paid for solid waste services via charges for bags, and stated (without supplying evidence) that "such a system encourages illicit dumping of normal and bulky domestic refuse. Moreover, the high price of the bags is an inducement to stuff too much into the bags so that they often tear". It is now reported[7] that due to the expense and problems caused by illegal dumping (as experienced by the solid waste departments), less and less communities are using this system. Where it is still in operation, the price of the bags does not typically cover the full costs of collection and disposal but, rather, an arbitrary fraction thereof.

Discussion

It appears that the use of systems in which charges vary for each collection according to the amount of waste collected is not extensive, and is currently on the decrease. While the potential advantages of increased equity and efficiency (compared to a flat-rate system) and administrative simplicity (where billing can be avoided) are widely recognized, they are thought to be outweighted by the disadvantages, of which the likelihood of an increase in improper dumping and litter seems to be viewed as the most serious. Such an increase has been reported in communities where the system has been tried, although quantitative data unfortunately seem to be lacking.

Interestingly, there seems to have been little discussion in Europe of the potential use of the system specifically to encourage waste reduction or resource recovery; rather, the Europeans have been more concerned with establishing an equitable and efficient method of financing than with reducing the generation of waste.

Furthermore, the concern for providing a satisfactory public service (with adequate protection of the public from the hazards caused by improper dumping and littering) is evidently stronger than any concern for waste reduction. For example, in many parts of Germany where the municipality decides the size of container to be used (and often supplies it), there is a trend toward requiring larger containers to remove any temptation to dump improperly[4]: in addition, the public can take small quantities of waste directly to the disposal site without charge, and there is always the possibility of placing wastes in the litter bins on street corners. In Denmark, also, solid waste collection and disposal are viewed primarily as a public service[8]; if it were found that the container provided to each household were not large enough, its size would be increased.[2] Households can also take wastes free of charge to container sites throughout the cities.

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[2] To accommodate temporary surpluses of waste, households can purchase bags at nominal cost. It is pointed out that the marginal cost of handling these bags is probably very low.

PRODUCT CHARGES[9]

At the present time, Sweden, Norway, and Finland each have taxes or charges on certain beverage containers; the French government has legislative authorization to introduce charges and is proposing to do so initially on beverage containers; and legislation enacted in 1977 in the Netherlands authorizes the imposition of charges on certain goods.

Nature and Purpose of the Taxes/Charges

Norway and Finland introduced taxes for the specific purpose of discouraging the use of non-refillable containers for beer and soft drinks. The Norwegian tax on non-refillables is about $.15 (plus 20% value-added tax) per container and represents a significant portion of the price of the beverage; when the tax was first introduced in 1974 this proportion was about 30%, but beverage prices have since risen, and it has now dropped to about 15%. The Finnish tax on non-refillables, introduced in 1976, represents a smaller, though still significant proportion of the beverage price; the tax is about $.08 on beer containers (some 6% of the price of the beer) and $.16 on soft drink containers (some 13% of the price of the drink).

The original purpose of the Swedish tax on containers for ready-to-serve drinks between 20 cl and 3 litres, first introduced in 1973, was to finance a freeze on certain food prices rather than to discourage the use of any particular kinds of containers. The tax is small (slightly more than $.02) and it is added to the cost of non-refillables, whereas it becomes part of the refundable deposit on refillables (i.e., it is paid on the latter only when they are not returned).

In France a proposal is being developed to impose a charge (under the existing legislation) on all containers ranging from 10 ml to 3 litres for wine, beer, soft drinks, fruit juices, mineral water, and possibly milk (although milk may be excluded for political reasons since it is currently subsidized). The charge would be 5-10 centimes (about $.01-$.02) per unit and would be intended to reflect the approximate cost of handling and disposing of the container once discarded. The tax would probably be levied when the containers are manufactured or assembled; the revenues would be collected by the Ministry of Finance and then disbursed to local authorities for solid waste projects including litter cleanup, demonstration trials, etc., as well as to industry (possibly) to finance the development of low waste technologies. The Ministry preparing the proposal is taking a pragmatic approach to the development of the charging scheme, keeping it as simple as possible; for example, no attempt would be made to "fine tune" the charge according to the disposability or other characteristics of a given container (except possibly that a distinction might be made between standard and non-standard containers). No reduction or exemption would be granted for the use of secondary materials in a container; for while this would almost certainly increase the level of resource recovery from the waste stream, it would tend to lessen the effectiveness of the charges in achieving their primary objective of reducing the rate of generation of wastes.

In the Wastes Act enacted during 1977 by the Netherlands parliament, there is provision for the introduction of "levies" both to limit the generation of waste and to provide revenue to carry out the provisions of the Act. The levies may be imposed on those who manufacture, import, hold in stock for sale, offer for sale, sell, deliver or use certain goods that are difficult to reuse, difficult to handle, cause an excessive increase in waste, or are likely to be littered.

However, it is now reported[7] that implementation of this provision by the present government is most unlikely, especially while problems of unemployment persist. The provision is considered too expensive to implement, and potentially too unpopular to be politically acceptable.

Effects of the Taxes/Charges

The Norwegian tax has been effective in preventing any growth in the use of non-refillable containers for beer and soft drinks. Although domestic bottlers have traditionally used refillables, beer imported from Denmark and Sweden was previously packaged in cans; now most imported beer is brought to Norway for packaging in refillable bottles. In Finland, also, there is very little canned beer.

In Sweden, on the other hand, while there has been a transition in the bottle sector from non-refillables to refillables, there was at first no change and subsequently an increase in the use of cans for beer (despite the fact that consumers must pay about twice as much for the same amount of beer packed in a can rather than a bottle). Other effects of the tax in Sweden, as reported by a government-appointed committee, include a reduction in the production of all bottles (due mainly to an increase in the number of trips made by each bottle, as well as to a shift to the use of larger bottle sizes) and various attempts to avoid the tax (e.g., by introducing new packages containing volumes outside the dutiable limits and by substituting undiluted drinks for ready-to-serve drinks). However, the committee also concluded that the tax has had no significant effects on costs, employment, or the environment.

Discussion

The taxes/charges have been applied differently according to the objective(s) intended. For example, it seems that the primary objective of the current French proposal for product charges on beverage containers is to improve market efficiency by internalizing in the producer's decisions the subsequent costs of handling/disposal (so that he has an incentive to take these costs into account). The monetary amounts involved are small (relative to the beverage costs) and so the charges are not expected to have major impact on the physical characteristics of the waste stream. The charges will, however, raise revenue that can be used to finance solid waste services. On the other hand, in Norway and Finland the objective has been specifically to discourage the use of non-refillable beverage containers, and therefore the latter have been relatively highly taxed.

In Sweden, the present duty on beverage containers was imposed not for waste reduction purposes but instead for an entirely unrelated reason (to subsidize a price freeze on certain foods); the amount is relatively small, and while there has been some shift from non-refillable bottles, the overall impact on the economy and on the environment has been reported to be insignificant. An increase in the duty is currently being proposed, with the intention of raising revenue to finance various anti-litter activities.

It is important to establish with what objective taxes or other fiscal mechanisms might be introduced in the United States. The product charging scheme that is being studied by the Resource Conservation Committee (as specified in the Resource Conservation and Recovery Act of 1976) appears to have the primary objective of internalizing solid waste management costs, and therefore seems most closely related to the French proposal. Careful attention should therefore be paid to developments if/when the latter is implemented. It should be noted that the charges currently proposed in France would apply only to beverage containers (whereas a U.S. scheme might apply to all consumer products), and that the French would grant no exemption for the use of secondary materials (on the grounds that this might encourage resource recovery at the expense of efforts to reduce the rate at which resources first enter the waste stream). One of the most striking features of the French approach is that every effort is being made to keep the scheme as simple as possible; rather than placing too much reliance on studies that seek to determine the theoretically "correct" level of charges, etc., the authorities are prepared to make reasonable assumptions and in general are adopting a pragmatic line.

A problem encountered in several European countries, and apparently common to the U.S. also, is that the use of taxes or other fiscal mechanisms for waste reduction purposes tends to be viewed with great suspicion by finance ministries and policy-makers in general. It seems that they frequently have difficulty in understanding that fiscal measures may be used not only for raising revenue but also for incentive purposes. Furthermore, finance ministries on the whole prefer to keep revenues and expenditures separate; they generally dislike funds to be "ear-marked" for particular activities (such as solid waste projects) over which they may have little control. An educational effort is required to ensure that those making decisions at least have a reasonable understanding of the advantages and disadvantages of fiscal approaches.

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THE ADMINISTRATIVE COSTS OF USER CHARGES

by

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INTRODUCTION

Since the passage of the resource Conservation and Recovery Act increasing attention has been focused on the problem of solid waste management.[1] More and more officials and citizens are becoming aware that solid waste disposal is not a simple matter, and that not only is the availability of sites for safe disposal of wastes rapidly decreasing, but that also the costs of such disposal are rapidly increasing. Responses to the problems of finite resources and finite numbers of suitable locations for the disposal of the residuals from these resources vary. For example, some groups attempt to encourage the recycling of used goods by instituting source separation programs for paper. Others attempt to develop procedures to create useful products from municipal waste, such as fuel or energy. A third group agrees that a market failure is at least in part responsible for the solid waste problem. Correction of this market failure, this group would argue, would do much to help solve the problem of increasing waste generation coupled with rising costs of disposal. It is the argument of this latter group which is addressed here.

Economists concerned about the market failure in solid waste collection generally cite the fact that generators of solid waste -- especially households -- do not face a price vector for the collection of such wastes which truly reflects the costs of solid waste handling. In the absence of such a price vector consumers' decisions are, in general, suboptimal. The lack of a true price for solid waste collection and disposal signals that in some sense society as a whole may not be as well off as it could be.

Whether or not this loss in social welfare can be remedied through the introduction of a properly specified price vector for solid waste collection and disposal services is only partly addressed here. The entire answer depends upon the relative magnitude of the gain in social welfare to be expected from institution of a price vector reflecting accurately the costs of solid waste collection and disposal services versus the opportunity cost of the resources used to implement and administer such a program. This paper attempts to quantify the resources which would be required to administer a user charge system for solid waste disposal service. The next section describes the economic framework in which society as a whole would benefit from initiation of a user charge system. While social welfare is most likely to increase when the type of user charge implemented is a marginal cost based system, practical considerations make implementation of such a system most difficult. Thus, Section III presents empirical evidence about the costs of administering various types of user charge systems. The final section of this paper presents some guidelines about when and how user charges can and should be initiated and summarizes the empirical information presented earlier.

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[1] Resource Conservation and Recovery Act of 1976. (IL 94-58).

ECONOMIC FRAMEWORK

Goods prices do not include waste handling prices, and waste handling prices do not, in general, vary with marginal changes in waste generation.

One of the "problems" of solid waste management stems from the fact that the costs of waste disposal are not included in product prices when consumers make their purchasing decisions. When households are faced with prices which do not vary with decisions made at the margin, the optimizing process is intercepted.

Most households in the United States receive refuse collection services from a public agency, and the most common means of financing those services is from general revenues.[2] Thus, the household is typically unaware that it pays about $35 per year for refuse collection and disposal.[3] Even if the household is aware of the costs of refuse collection, it is not able to impact its own charges through individual behavior; there is thus no pecuniary reason for a household to cut back on refuse generation.

Pricing schemes for users of refuse collection services fall into two broad categories: those where the marginal cost is zero and those where it is positive. All methods of financing refuse collection can have an impact on refuse generation; however, those user charge systems with a marginal price of zero will affect production of waste only through the income effect. Such systems either charge the household a flat fee or finance refuse collection from general revenues. Clearly, the higher the fee (or cost financed from general revenues) the smaller the disposable income of the household and (assuming that refuse generation increases with income) the smaller is the quantity of refuse generated.[4] Systems where the marginal price is positive should impact the volume of refuse generated through both a substitution and an income effect. Such pricing mechanisms have the very desirable attribute of causing households to consider the implicit cost of disposing of the refuse component of a good, allowing households to trade off goods with respect to their total cost--purchase price plus implicit disposal cost.

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[2] Savas and Stevens, "The Cost of Residential Refuse Collection and the Effect of Service Arrangement," Municipal Year Book 1977.

[3] The Cost per ton for refuse collection average about $20; using a household generation rate of 1.7 tons, the household pays an implicit or explicit fee of about $35 per year. See Savas and Stevens, ibid.

While the theoretical superiority of user charge systems with a positive marginal price are quite clear, they present problems in that they are difficult and costly to implement. In order to affect the marginal consumption and disposal generating decision of the consumer it is necessary for the user charge plan to contain a marginal price for refuse generated. In fact, a true marginal pricing scheme does not exist. The closest approximation to such a marginal price system is the one in which households are charged by the can or container of refuse presented for collection. Since the contents of a container of refuse can vary widely, even this system does not truly present the consumer with a valid marginal price vector to impact on his marginal consumption decision.

In short, economic theory would indicate that institution of a pricing scheme or user charge system for refuse collection which truly charged consumers for the disposal of each marginal item of refuse generated would (a) cause a reduction in waste generation due to both the income and the substitution effects and (b) result in an increase in social welfare to the extent that foregone use of resources for waste disposal and the value of goods not disposed of exceeds the value of resources used in administering the program. Administrtion costs are defined to include the costs of billing users of the solid waste service, collecting from delinquent accounts, enforcing the system, and handling of complaints arising solely from the user charge system. To be complete, one should state that administrative costs should be net of any changes in productivity arising from the imposition of the system, as, for example, might occur were the system that of metered bags.[5] In the following discussion, however, no

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4. The value of resources used in administering the program can be defined as equal to not only straightforward administrative cost but also costs associated with other activities which may be reinforced via the imposition of the user charge system. For example, littering may increase when user charges are unpaid. As the cost of litter collection exceeds the cost of regular solid waste collection, this may represent (if the increase in the propensity to litter is great enough) a real drain on resources. See McFarland, et.al. Comprehensive Studies on Solid Waste Management, Final Report, Sanitary Engineering Research Laboratory Report 72-3, University of California, Berkeley, 1972.

5. Hudson, Issues in Pricing Solid Waste Management Urban Systems Research and Engineering, Inc., Cambridge, Massachusetts 02138, #68-01-4362 for USEPA, June, 1978 finds significant savings in costs due to productivity increases associated with initiation of a metered bag or other user charge system.

attempt will be made to account for anything other than the straightforward administrative costs of a user charge system.

From a pure, maximize-social-welfare-point-of-view, then quantification of several factors is an essential first step in evaluating whether a user charge system is desirable. Assuming that one institutes a marginal based system in a market where prices for refuse collection are already present, one first needs to know the price elasticity of refuse generation. From this information, together with known data on current refuse generation patterns,[6] it is possible to calculate the quantity of resources which would be freed from entry into the disposal stream and thus saved for other, presumably superior, uses by society. Second, the quantity of refuse going into recycling patterns should be determined. These quantities would already be included in the first category as refuse not going to the final disposal site; they should be considered as resources newly being directed to an optimal use, as a direct result of the institution of the new pricing scheme. These two factors represent the benefits to society of the user charge system. No attempt is made here to value this latter benefit stream. In order to estimate net benefits to society, it is of course necessary to know the true marginal social cost of refuse collection and disposal. Net costs are the costs of administering the system less the net costs foregone for refuse not generated and not collected.

While this discussion is straightforward and presents no new theoretical insight, it does highlight the basis on which the user charge system can best be evaluated. First, how large are the benefits to society from institution of this system? Where the system is one in which a flat or lumpy user charge system is instituted instead of a true marginal cost pricing scheme, it is possible that there might be no reduction in refuse generation and, thus, no social benefit. Without any attempt being made to evaluate the benefits from reduction of the consumption stream, we can say that a user charge system is desirable where the value of resources freed from refuse collection and disposal activities is at least as great as the cost of administering the program. An attempt at this final calculation is presented in the next sections.

EMPIRICAL EVIDENCE

Two approaches will be used to evaluate the magnitude of administrative costs for user fees relative to the cost savings resulting from initiation of such fees. First, two cities' experience with such fees will be presented. Each has a user charge system which is variable by quantity of refuse collected. The cities differ dramatically in how the charges are administered and consequently, in costs. The low cost city illustrates a "best case" for the administrative cost of a user charge system while the contrast between the two cities highlights procedures to be followed in instituting an efficiently administered system. Second, overall data is presented for thirty-eight cities located throughout the United States that have municipal refuse collection service and bill households for this service. These average administrative cost data are compared with refuse generation and the costs of service delivery to obtain average cost figures for administering a user charge system.

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[6] Several studies have indicated that refuse generation increases with income. See Center for Urban Studies (A Condensation of Battelle Columbus Laboratories) Some Economic Factors Affecting Demand for Municipal Collection of Household Refuse, University of chicago, August, 1973, 47 pp., J. McFarland, et. al. Comprehensive Studies of Solid Waste Management, Final Report Sanitary Engineering Research Laboratory, College of Engineering and School of Public Health SERL Report No. 72-3. Berkeley, California, University of California, (May, 1972).

Having estimated the administrative costs of user charges on a best case and an average case basis, these data are related to best case and average case estimates of the cost savings to be expected from imposition of the user charge system. These data are drawn from a 1974[7] survey as well as other engineering and economic estimates. Together, the probable impact of user charges can then be evaluated.

Best Case-Worst Case

The two cities selected to illustrate the characteristics of an efficiently designed user charge system are both located in the Western part of the United States.[8] Each was paired with another city as part of a series of case studies comparing cities whose costs differed but which were alike in refuse collection service delivery, scale and location. The matched cities' respective residuals from an estimated cost equation were at least two standard deviations apart, with one city's residual being positive and the other's negative. One city selected for discussion here was the low cost outlier of the matched pair located in the Mountatin Region while the other was the high cost outlier from the matched pair located in Northern California. The high cost outlier, Norcahigh, is, not surprisingly, here the city with the high costs for administration of the user charge system. The low cost outlier, Mountainlow, is associated here with an extremely efficient low cost system for administering a user charge system. The costs of refuse collection and administration are greater in Norcahigh than in Mountainlow for several reasons, one of which is different ways responsibility for billing and collection of fees is allocated in the two cities.

Norcahigh has a very complex way of administering their variable fee user charge system. Norcahigh has a contract with WCF for the collection of residential refuse. WCF is a national firm that has been in business in this city since the mid-1970's. Residential service in Norcahigh is once a week curbside at the base rate of $3.11 per month per household for two cans. Additional cans are collected at $1.00 per month per can. A resident may also pay a higher fee for backyard service.

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[7] See Savas, ed., The Organization and Efficiency of Solid Waste Collection, Lexington Books, Massachusetts, 1977.

[8] Stevens, Norcahigh-Norcalow available from Ecodata, 1700 Broadway, and Mountainhigh-Mountainlow.

The Office of Property Code Enforcement in the City Government is specifically empowered to enforce contract provisions. It deals with delinquent accounts and unanswered complaints, and is the liaison with the health department for matters such as vehicle inspection. This office is run by a deputy health officer; twenty-one of its employees spend part of their time monitoring the refuse collection contract. In the last quarter of 1976, 1,000 liens against property were issued due to delinquency in payment of refuse bills. The large numer is no doubt the result of a notably cumbersome billing procedure.

WCF must act as a bill collection agency as well as a refuse collection firm. More than ten full-time employees work at WCF to update the list of accounts to be billed for refuse collection service. Owners of property are supposed to institute services themselves, but, in fact, the firm generally must itself identify new residents in order for billing to begin. Once a resident has been billed, the firm's collection problems have only begun. If a resident does not pay, very specific procedures are followed. First, WCF sends a delinquency note. If there is no response to the delinquency note, after sixty days, WCF sends a second delinquency notice and simultaneously files a copy with the health officer indicating who has not paid and how much is due. If the bill remains delinquent for seventy five days, WCF gives the bill to the city for lien and special assessment proceedings. After twenty days, the health officer can send the owner notificaion that he owes the bill plus ten percent charge and also runs the risk of incurring a lien on his property for the delinquent amount. At that time, lien proceedings are begun and the health officer notifies the city council which in turn posts a time for a hearing on the proposed lien. After the hearing, if the city council decides the lien is justified, it is established as the greater of $25 or ten percent of the refuse collection service charge. The lien is recorded, the owner is notified officially, and proceedings to have the sum of service, delinquency charges, administrative and assessment charges specially assessed against the owner's property begun. This occurs if the lien is still not paid. If the special assessment is approved upon hearing by the city council, it becomes part of taxes payable.

Two private firms, Oaks & Sons and MoLo, service residential accounts in Mountainlow. Each has an exclusive area and is franchised to service all households in the area. MoLo collects mostly from recently annexed areas of MoLo county, while Oakes & Sons picks up from the majority of households in Mountainlow. Oakes & Sons has been in business for thirty-one years. For a fee, households have a choice of location (curb or carry out) and quantity of refuse to be collected. In Mountainlow, the base fees of $2.25 per month for one can, $2.75 for two cans, $3.10 for three cans, and $3.45 for four cans also include costs of billing and disposal. Unlike in Norcahigh, however, in Mountainlow these two functions are performed by the city government, which takes 21% of gross fees to pay for billing costs, disposal expenses and franchise fees. In both cities, yard trash is collected along with regular commercial customers on residential routes, although the fees for commercial establishments generally differ from those for households.

Mountainlow's City Attorney and the Council take responsibility for writing franchise agreements, for selecting the refuse collection contractor, and for determining annual charges. In addition to these functions, this city has a separate complaint and billing department, employing an equivalent of four full time persons to provide the complaint handling and billing services for refuse collection.

Mountainlow's City Attorney and the Council take responsibility for writing franchise agreements, for selecting the refuse collection contractor, and for determining annual charges. In addition to these functions, this city has a separate complaint and billing department, employing an equivalent of four full time persons to provide the complaint handling and billing services for refuse collection.

Mountainlow operates a computerized billing system for Oakes & Sons, employing two full time equivalent persons in that function. Residents are divided into groups, each of which receives quarterly bills on different months. The city receives both weekly and monthly status reports on all accounts. Customers wishing additional service on an occasional basis attach a coupon (obtained from Oakes & Sons) to each extra can or bag of refuse; the loader remits this coupon to the city, and the resident is billed for the additional service on the next regular mailing. The city provides Oakes & Sons, at no charge, with a monthly printout of the status of its accounts. Oakes & Sons must pay the city for additional computer services, such as mailing lists.

The city remits a monthly check to Oakes & Sons. The amount the firm receives is gross receipts less bad checks, a 3% franchise fee, a 6% billing fee, and a 12% landfill fee. The city's concern with low cost service is evidenced by a current controversy about the amount charged the city by the county for use of its landfill. Since 1973, Mountainlow has claimed that the county is charging too high a landfill fee (i.e., 12% of receipts), since its charge to individual residents is much lower. The city has withheld half of the 12% it owes, holding the 6% in a trust account. Despite the disagreement, Oakes & Sons in effect pays 12% of gross receipts for disposal, and, netting out all charges, receives (in 1976) $1.78 per household per month for refuse collection services.

Mountainlow has a city operated complaint handling facility. Two persons work full time receiving complaints and monitoring their handling. The city opened its complaint and information center in 1974. It is staffed by a former public relations consultant, and his assistant. Residents usually call Oakes & Sons with a complaint. If the problem is not rectified, they then call the city. When the complaint office receives a call, a staff member writes it up, trying to record the complaint in the caller's own words. The office personnel will try by tactful, questioning to discover whether the resident has observed all the "hard card" rules printed up and distributed by Oakes & Sons. Complaints are followed up by the city sanitarian, or the police department if the complaint involves a tip-over by dogs.

There is a regular daily procedure for handling complaints. The sanitarian comes to the complaint office each day at 1:30 P.M. He collects all the complaint slips and investigates by contacting either the resident or the private contractor. Attempts are made to resolve complaints the same day they are received. This is of great concern to the city.

The main complaint is missed collections or litter around the can. Complaints increase during the summer months, as corroborated by the complaint officer. Complaints are categorized by number and type. Indeed, there is even a list of "chronic complainers". As is often the case, missed collections are the most common problems, with lids off the can the second most frequent complaint.

Mountainlow is involved in the service on several levels. On a day-to-day basis the city monitors the quality of the service through its complaint system. On a monthly basis it monitors the financial activity of the firm through its billing system. Lastly, the city has very specifically defined in its ordinances the parameters of the service it wants and the fair price that it will pay. Approximately four full time equivalent municipal employees are devoted to the refuse collection service. These employees are paid from the franchise and billing fees charged to the contractor.

Table 1 presents a summary of the best-worst case history of administrative costs for these variable fee user charge systems. Both Norcahigh and Mountainlow have quite similar collection costs per household--$25.29 and $23.40 respectively. Due to differences in generation rates in the two cities, the cost per ton collected in Norcahigh exceeds the $13.47 amount achieved in Mountainlow by 35%. The different administrative procedures followed by the two cities for billing results in an even more striking cost difference. Mountainlow's cost per household per year for billing is but $1.64, while that for Norcahigh is $4.48--over four times more than its comparison city.

While administration costs of a user charge system are defined here to refer mostly to the expenses associated with billing, some extra complaints may arise due to the charge system, and these expenses should also be included. For example, households could complain about inaccurate billing, or about service so unsatisfactory as to justify non-payment of invoices. While there is no evidence to indicate that the type of complaint or frequency of complaint received in these two cities is any different from that received in cities without user charges, the costs of complaint handling are presented in Table 1. Including these costs as part of administrative costs of user charges would result in an overestimate of the magnitude of that cost. As shown on Table 1, the complaint handling costs in Norcahigh averaged 5.1% of the annual per household collection costs while the same function in Mountainlow averaged at 8.6% of the annual collection costs per household. Together, then, the administrative costs of billing and complaint handling amount to 22.9% of collection costs in Norcahigh--$5.97 per household per year--and 16.5% of collection costs in Mountainlow--$3.86 per household per year. Excluding complaint handling reduces the annual per household costs for administration to $4.48 and $1.64 respectively.

It is clear that the cumbersome procedures adopted by Norcahigh for billing result directly in very high costs. The smoother-working procedures in Mountainlow contrast sharply with those in Norcahigh. Billing by the same

TABLE 1. REFUSE COLLECTION COSTS: COMPARISON OF NORCAHIGH AND MOUNTAINLOW

Cost measure	Norcahigh	Mountainlow
1976 costs		
Total cost	$3,160,978	$468,000
Number of households served	125,000	20,000
Cost/ton	$18.25	$13.47
Cost/cubic yard	$ 4.44	$ 3.36
Cost/household	$25.29	$23.40
Billing data		
Billing personnel (full time equivalent)		
City	10	2
Firm	10	2
Billing costs as % of cost/household	17.8%	7.9%
Cost/bill	$ 1.12	$.41
Complaint data		
Complaint personnel (full time equivalent)		
City	4	2
Firm	2	.5
Complaint cost as % of cost/household	5.1%	8.6%

*It should be stressed that the fees charged by both these firms are at least 25% less than the expected costs for a municipal agency delivering the same services to its residents as do these firms to the residents of these cities. All costs are exclusive of disposal fees and percentages are as percent of collections costs only.

agency which has responsibility for termination of service for non payment seem highly desirable, as does joint billing for several services. Billing for utilities and refuse collection at the same time makes record keeping of new arrivals in the city much easier than when refuse collection is separately billed. New arrivals must have utilities officially connected in order to start receiving service whereas this is not necessarily required for waste handling--collectors often service refuse containers set out at the proper time and place. In short, joint billing with utilities facilities accurate billings of all service recipients, decreases the deadbeat problem, and results in lower administrative costs.

Survey Results

In a 1974 survey of 101 cities providing municipal refuse collection services to residents, cost data was carefully collected on site using consistent cost categorizations.[9] One of the categories for which data was obtained was billing costs in cases where cities had user charge systems. Thirty-eight of the 101 cities surveyed had user charge systems of one type or another: five based their charge on quantity collected while the remainder charged a flat fee or variable fee based on the frequency or location of pickup service selected by the recipient households. Figure 1 and Table 2 display the data collected in the survey.

The data show little relationship between billing costs and city size, though the variance in billing cost as a percentage of the total costs of collection does decrease with increases in city size. Several other factors were calculated from these survey data. The average number of households served in the cities with user charges studied here was 14,513; the market ranged from under a thousand to almost ninety thousand. The average cost per city for billing was $12,000. This amounted to about eighty-six cents per household per year for billing expenditures—the range was from a disconcertingly low three cents per household per year to $2.75 per household per year. Of the thirty-eight cities in the sample, 43% used joint billing. Contrary to what one might believe, those cities which used joint billing had higher costs attributable to residental refuse collection bills than did those cities which billed refuse collection separately. This result is so counterintuitive that one must conclude only that cities where more than one department pays for billing are more likely to keep accurate records of the true costs of billing and to enable accurate separation of these costs than do cities where billing occurs within a single department. Very often, where billing occurs within a single department, in collecting the cost data, interviewers would be willing to lump together some of the true costs of billing (for example, the cost of a clerk's time) in other categories rather than separating them out, so long as the total cost figures for refuse collection service delivery were accurate. This readily explains why the cost per household for joint billing might exceed those for single billing.

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[9] See Stevens, "The Cost of Residential Refuse Collection" in Savas, ed., op. cit. for a description of the survey.

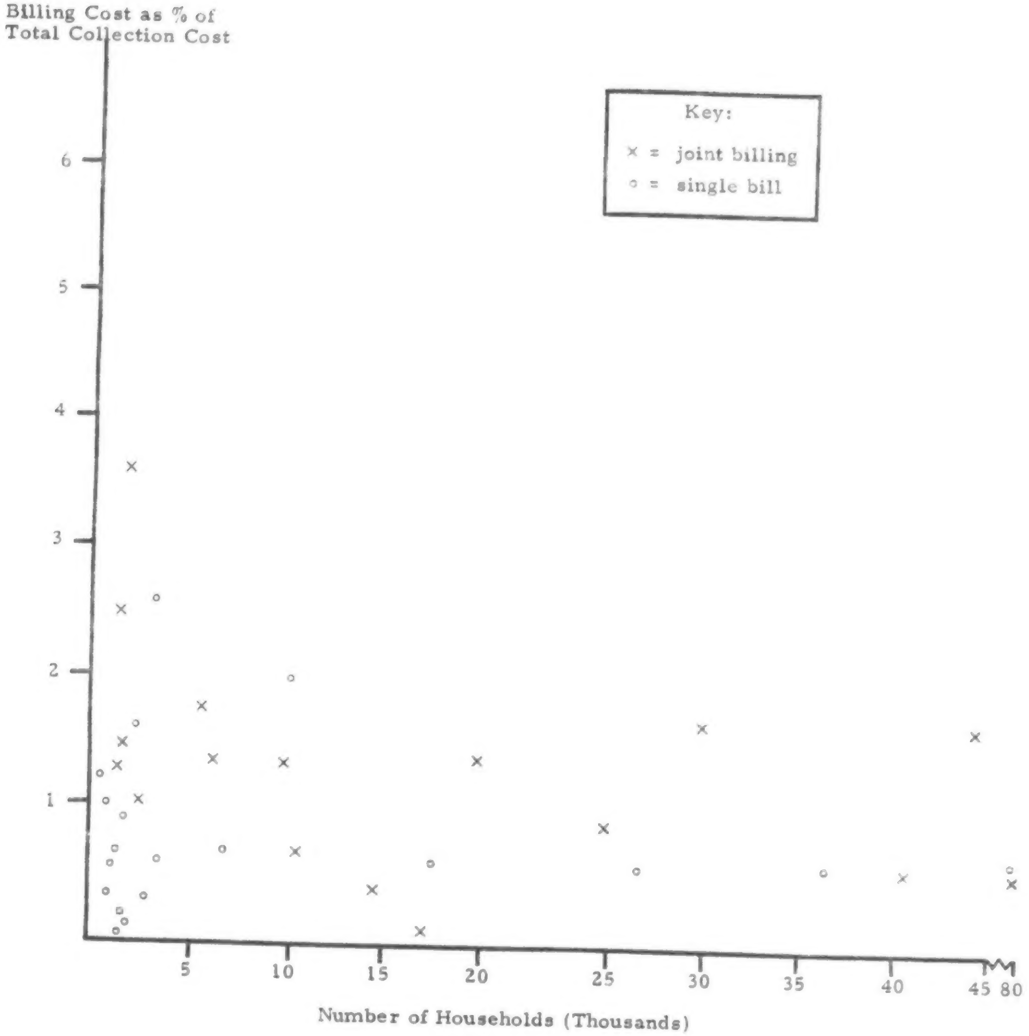

Figure 1. Billing costs by city size.

TABLE 2. USER CHARGES AND ADMINISTRATIVE COSTS: 1974 DATA

	Mean	Minimum	Maximum
Households served	14,513	762	88,143
Service level			
% of households with 1x/week service	30%	0	100
% of households with curb or alley service	67%	0	100
Monthly charge per household	$2.70	$1.00	$6.00
Billing costs:			
Average cost/city	$12,506	$50.00	$88,312
% of cities with joint billing	43%	-	-
Average billing cost per household	$.86	.03	$2.75
Average billing cost per household for cities with joint billing (n=18)	$1.28	.11	$3.75
Billing cost/Total Collection Cost	3.18%	1%	6.83%
Billing cost/Total Collection Cost for city with joint billing	3.80%	1%	8.33%

Overall, the average billing cost as a percentage of collection cost was 3.18%. In cities with joint billing an average of 3.8% of collection costs were attributable solely to the administrative expenses of billing for refuse collection services. As this number seems more reliable than that for single billing of refuse collection services, we can take the 3.8% figure as a low estimate of the administrative cost of user charges.

Although the 3.8% figure may indicate a reasonable level for the expenses of instituting a user charge system, it should be remembered that the administrative cost of instituting a quantity based user charge system might be much greater than that figure. This would be so because charging on the basis of quantity requires more interaction between the billing system and the refuse collector himself. When the refuse collector himself must be involved with determining the eligibility of a household's presented refuse for collection at each stop, work productivity is probably decreased, which may in effect increase the administrative cost of a system more than with a non-quantity based user charge system.

While not as detailed as one might like, these data do represent some of the best information on the actual costs of administering a user charge system. Further, detailed study on these matters would of course tend to increase the assurance with which policy decisions could be made.

CONCLUSIONS AND POLICY IMPLICATIONS

The empirical evidence has shown that the administrative cost of user charge system are on average likely to be at least 3.8% of the total cost of residential refuse collection. Indeed, for two cities where billing costs were collected with great care and detail, it was found that the administrative cost of billing ranged from a low of 7.9% to a high of 17.8% of collection and disposal cost per household.

The 3.8% figure is representative of costs where billing is mostly done on a non-quantity basis and by public agencies billing services jointly. As such, it represents the low end of the administrative cost scale. The 7.9% figure is consistent with a quantity based user charge system where the billing is performed by a public agency billing jointly for several services at one time. The 17.8% figure, the high end of the administrative cost scale, is obtained when a private firm bills individually for a quantity based service.

These three data points can be used to derive estimates of the likely impact of imposition of user charge systems on social welfare. Two scenarios for imposition of the quantity based charge will be considered:

1) imposition of a quantity based charge over an existing flat fee user charge system, and

2) imposition of the quantity based user charge system over a service financed through general tax revenues.

Both of these systems are hypothesized to impact household refuse generation and the costs of refuse collection in similar fashion. Financing the service through property taxes as compared to a flat fee user charge differently affects aggregate refuse generation only to the extent that the incidence of the property tax differs from equality across individuals. If the property tax incidence is sufficiently regressive to approximate the impact of a flat fee user charge in a heterogeneous community, then little difference in aggregate refuse generation would be expected as a result of the financing scheme. Many smaller communities are quite homogeneous in terms of income, and there the probability is high that the incidence of the flat fee user charge and the property tax would not be too different. It is assumed, then, that household refuse generation is the same under the flat fee or the property tax financing scheme. The imposition of a quantity based user charge system on these financing schemes will, however, result in different increases in the administrative costs of the two systems.

Figure 2 portrays graphically the marginal savings and costs to be expected from imposition of a quantity based user charge system on the two financing schemes. In both cases, households generate Q refuse prior to imposition and Q refuse post imposition. The flat fee system is shown as saving some of its pre imposition billing costs as refuse to be billed for decreases after imposition of the user charge system.

Both systems also reap whatever cost savings are attributable to collecting and disposing of a reduced quantity of wastes. The quantity based user charge system is showed as causing the equilibrim price to equal 1.079 times the property-based cost of refuse collection. There is, obviously a greater increase in billing costs for the property tax financing scheme than for the flat fee user charge system. Clearly, then imposition of the quantity based system is desirable in either case if the extra administrative costs do not exceed the cost savings from reduced generation of refuse.

Estimating the size of the cost savings from reduced refuse generation is difficult. There is no clear cut evidence about households' reactions to imposition of such a charge. Studies of existing cities with quantity based user charge systems indicates that the price elasticity of refuse generation may be very low, but this evidence is by no means conclusive. Rather than estimate these refuse generation responses directly, then, they will be calculated as a residual, indicating the minimum response necessary to offset increased administrative costs. These estimates are presented in Table 3.

Table 3's data is based on the following general assumptions: that the additional administrative costs imposed in moving from a property tax financing scheme are $2.96 per household per year; that the comparable figure for moving from the flat fee user charge system is $1.53 per household per

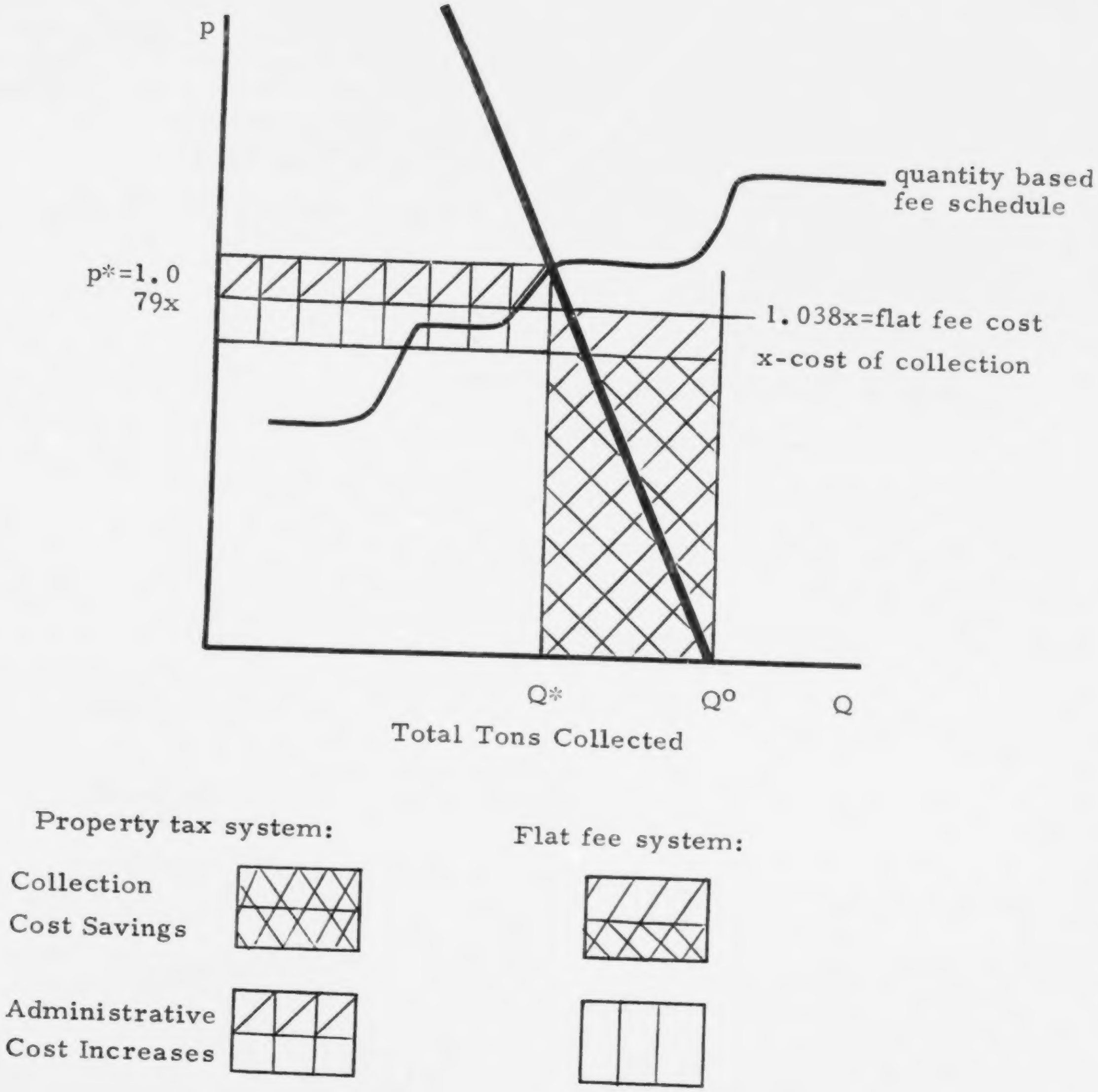
p
p*=1.079x
quantity based fee schedule
1.038x=flat fee cost
x-cost of collection
Q*
Q°
Q
Total Tons Collected
Property tax system:
Collection Cost Savings
Administrative Cost Increases
Flat fee system:

Figure 2. Costs and savings from imposition of a quantity based user charge system.

TABLE 3. REFUSE GENERATION RESPONSES REQUIRED FOR ACCEPTABILITY OF QUANTITY BASED USER CHARGE SYSTEM

General assumptions:

Refuse per household, pre imposition	1.5 tons/year
Cost per household, pre imposition	$37.50/year
Extra administrative costs household	
Property tax to quantity based user fee	$2.96
Flat fee to quantity based user fee	$1.53

COST SAVINGS FROM REDUCED REFUSE GENERATION

Alternatives:	Required refuse generation reduction*	
	Property tax to quantity based user charge	Flat fee user charge to quantity based user charge
Cost savings = 90% of average collection costs	8.8%	4.5%
Cost savings = 60% of average collection costs	13.1%	6.8%
Cost savings = 25% of average collection costs	31.6%	16.3%

* Reduction required such that cost savings will equal increase in administrative costs.

year.[10] Three alternative assumptions are made regarding the collection cost savings which would be experienced as a result of collecting less refuse at each stop: savings will be 30%, 60%, or 25% of what the average cost of collecting the refuse no longer being generated would have been. The 60% figure results from engineering models, while the 25% figure is a point elasticity calculated from econometric work.[11]

If cities are efficient and can reroute and reschedule in response to refuse generation reductions, then cost savings can be high, and the required refuse reduction to justify the quantity based user charge system is quite low--4.5 to 8.8%. The converse also holds true. These simple calculations highlight the fact that for successful imposition of a quantity based user charge system, a streamlined administrative system and a somewhat price sensitive refuse generation behavior are only necessary conditions. Sufficient conditions require also that the refuse collection organization itself responds efficiently to the changed levels of demand for its services. Development of procedures to aid managers in effecting these efficient responses should be a cornerstone of any quantity based user charge program.

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[10] These costs are calculated as a percentage of baseline collection costs. No downward adjustment is made for reduced generation affecting this product, as it is assumed that admnistrative cost will be more sensitive to number of accounts billed than to the quantity of refuse generated.

[11] See Stevens, and Hudson, Work under progress for the Resource Conservation Committee, E.P.A., 1978 and op. cit. 1978.

SECTION 3

PRICING AND THE EQUITY OF SOLID WASTE FINANCING

"Equity Considerations in User Charges for Residential Refuse Collection and Disposal" (Roger Bolton).

"Pricing Municipal Refuse Service: Potential Effects on Municipal Budgets" (Kenneth L. Wertz).

EQUITY CONSIDERATIONS IN USER CHARGES FOR RESIDENTIAL REFUSE COLLECTION AND DISPOSAL

by

ROGER BOLTON

THE GENERAL CONTEXT

I first want to set the context for considering equity considerations. We are concerned with the distribution of effects of a change from one system of public sector solid waste management (henceforth, SWM), call it System A, to another system, call it B. We are motivated chiefly by the possibility that System B has user charges, System A does not. Indeed, in many discussions of this problem writers implicitly or explicitly assume that System A and System B differ only in that B has charges and A has some other financing method. More than one author discusses the equity effects of user charges as if the conditions of refuse management are unchanged when changes are imposed. By conditions I mean to include the aggregate quantity of refuse and the costs of handling it, as well as the distribution of those aggregates over households. Costs here must include the cost incurred by households as well as the public sector.

I think that is too restricted and too hypothetical a comparison. In the real world, if System B includes user charges it will probably also show other changes from System A. Those other changes will affect the total costs in the public sector. There are the billing costs, for one thing—every one mentions them. But in addition there are changes in household behavior, induced by the introduction of charges. Those changes in household behavior are precisely the changes which are emphasized in discussions of the efficiency aspects of charges. If the price system "works" when user charges are introduced, then the aggregate quantities of refuse and the aggregate public sector costs of handling it will change. And so will the public sector costs of handling any one household's refuse; one cannot assume the costs imposed on the public sector by a household's refuse under System B will be exactly the same as they were under System A. Nor can one assume that the costs imposed by an income class's refuse will be the same. Finally, the changes in household behavior will change the aggregate costs incurred by households, and they are relevant for an analysis of equity. Again, one cannot assume the distribution of household-incurred costs is the same under System B as it was under System A.

The upshot of this is that the analytical and empirical problem is one of "balanced budget incidence," rather than one of "differential tax incidence" (11, ch. 10). It is balanced budget incidence because both the income and expenditure sides of the public budget will change: the expenditure side changes because quantities of refuse and costs of handling change; the income side changes if income exactly covers costs. The literature seems to have sidestepped this problem, and dealt with the problem of differential tax incidence, instead. Writers have used differential tax incidence, because they have assumed total expenditure on SWM is constant, and also the expenditure required to handle each household's, or each income class's, waste.

No doubt, with the uncertainties and controversies over tax incidence, especially over property tax, analysts have felt they had enough on their plates if they tackled the differential incidence problem. They have also had the problem that most of the data on public sector costs are for cities where System A is in place, and System B has never been tried. Then, too, some writers feel the differences in costs between System A and System B are not large enough to worry about -- not large enough to require a balanced budget incidence model. They may argue that my initial point is rather academic. That may be. However, I do find it strange that there is so little discussion of the point, in analyses of a policy change which is recommended in the first place on efficiency grounds. Economists recommend charges because they will induce changes in the quantities of refuse offered by households for collection and disposal, and, therefore, changes in public sector costs.

CHANGES IN THE CONDITIONS OF SWM

Changes Initiated by the Public Sector

First, we may have significant changes in the range of choice offered by the public SWM system. The move to user charges may be accompanied by changes in the frequency of collection, the regulations on types of containers, the locations at which containers will be picked up (curb side, back yard, etc.), regulations on separation of garbage frm other refuse or separation of newspapers from other refuse, the availability of bulky item pickups, etc. Whether the range of choice will be expanded or narrowed will depend on specific circumstances in the municipality. The nature of the previous system, the impetus to user charges in the first place, and the socioeconomic characteristics of the residents are all relevant. It's hard to generalize, and one should probably do no more than point out the need to keep these things in mind when analyzing the equity effects of a change in policy.

Are such changes important in practice? Can't one assume them away when the financing method is changed? I think it would be wrong to do so, for some very definite reasons. For one thing, SWM is a politically-sensitive function, and changes in it will produce "flak" for the managers. That is especially true if changes include a move to an untested and basically unpopular--in the short run--pricing system. If solid waste managers even thought about introducing any other changes in their system, they may decide to bite the bullet and introduce them along with charges. They may prefer to endure one period of intensive criticism and then be done with it, rather than endure several recurring periods of criticism.

For another thing, some changes in the conditions of collection and disposal may be called for by the efficient and cost-saving administration of the user charges scheme itself.

But the most important reasons for expecting multiple changes by the solid waste managers are different. One of the reasons is that a change to user charges is likely to be stimulated by a crisis or quasi-crisis situation in the municipality. It may be a budgetary crisis, or a landfill-space crisis. In either case, user charges are likely to be part of a package tc cope with the problem. The municipality may eliminate some costly service options, such as frequent collection, or backyard pickup. It may eliminate these altogether rather than go to the trouble of pricing them correctly. It may also try to increase resource recovery revenue to the municipality or to reduce landfill space requirements; for example, it may require that newspapers be separated out from other items.

Solid waste managers may find it very difficult--very costly, that is--to maintain the same environmental standards when they substitute System B for System A. We often worry, for example, that some households will respond to the user charges by increasing what is euphemistically called "alternative disposal". This may include illicit disposal by dumping the rubbish in vacant lots and parks or open burning. It may also include increased use of garbage disposals in the kitchen, which transfer the enironmental burden from the SWM system to the sewage disposal system, and increase the public sector sewage costs and/or the pollution damages accordingly. Some analysts discuss user charges in solid waste under the explicit assumption that environmental standards are unchanged. This seems wrong. Either there will be increased public sector costs to insure the maintenance of the standards, or else the standards will not be met. In either case, the usual limited approach of differential tax incidence is incomplete, and misleadingly so. In the first case, public expenditures will be affected. Also, in most jurisdictions sewage disposal is already financed by user charges, the equity aspects of which may be quite different from those of the general property tax which one usually associates with the SWM function. In the second case, the distribution of increased environmental costs is itself an issue; many of these costs are likely to bear heavily on the poor.

Changes Initiated by Households

There are at least three kinds of changes here. At the risk of dull repetition, I point out again that they are the very things given the biggest play in the literature on efficiency, sometimes by authors who go on to ignore them in their analysis of equity considerations. Furthermore, the basic theory of household behavior inescapably concludes that the income levels of households may be a prime determinant of the changes; that leaves us with an equally inescapable conclusion that the equity or income distribution impacts of added household costs needs some careful analysis.

Households may initiate these changes:

1. Change in consumption habits in general. Different market goods and services have different amounts of solid waste attached to them; user charges for solid waste cause effective prices of goods and services to change, theoretically leading to changes in consumption. Thus, solid waste charges might affect the consumption of newspapers, of frozen food, of beverages, neat lawns, and other things. The net impact on the welfare of the household after it has made its optimizing adjustments will vary with income and with some important family characteristics, such as the opportunity cost and psychic cost of time spent in waste handling by various members of the family.

2. Change in household time spent in handling waste. Time may be spent in alternative disposal, separating kinds of waste in order to meet new regulations or to earn money from recycling, carrying containers longer or shorter distances for pickup, storing waste more carefully in order to reduce the frequency of pickup service, etc. Unlike in the previous paragraph, here we are concerned with the impact on the household of the changes in its use of time per se, rather than the impact of the changes in its consumption of market goods and services. However, the same determinants mentioned in the previous paragraph are operating here--income and characteristics affecting the opportunity and psychic cost of using time in various ways.

3. Change in household money expenditures on some particular market goods and services, which are used in solid waste management in the household. Chief examples are items used in alternative disposal, such as automobile and kitchen garbage disposal costs, and items used in waste storage, such as compactors and containers. These are merely a subset of the wider set of changes discussed under Section 1, consumption habits in general, but it is useful to distinguish them because user charges set up definite incentives for alternative disposal and storage methods. Again, income and value of time are important determinants of the changes.

My emphasis on household time and on expenditures for market goods and services is inspired by a Becker-Lancaster household production model. That model is fruitful in analyzing the household responses which need to be taken account of; in the household production approach, some broad good like "household environmental quality" is an argument in the utility function. The household chooses between its own production activities and public management services as substitutes in providing environmental quality; the presence or absence of user charges for the public management services obviously affects that choice. But user charges also affect the price of environmental quality per se, no matter how the household achieves it, so they affect the consumption of household environmental quality relative to other things which give utility. Thus, they affect consumption habits in general.

There are also production functions for the household activities in question, the inputs in which are time of family members and market goods and services. User charges affect the optimum level of these household production activities, so they affect the optimum allocation of family time and also the purchase on the market of inputs into production. Thus, when all the household's reactions to charges (and accompanying public sector changes) have been worked out and a new optimum allocation of time and money income achieved, it is possible that all sorts of things have changed. The mix of environmental quality and other things in the utility function must be achieved simultaneously with the mix of household production activity in waste management and the use of public SWM services, and both must be achieved simultaneously with the optimum utilization of time and market-purchased inputs in household production activities. After all the dust has settled, the household may be better or worse off, depending on the balance between its user charges and the amount of taxes it saves, but also on the nature of the accompanying changes in the public system, on its own household production functions, and, of course, on its tastes.

Clearly, the task of equity analysis theoretically should include a prediction of how the net result of these household decisions varies across households at the same income level. That is essential for the question of whether "equals" are affected "equally," or the "horizontal equity" question. It also must include a method for expressing the net result of the decisions in some kind of monetary equivalent form, such as a "consumer surplus". And, finally, it must include a prediction on how the results of household decisions are correlated with income levels--that is essential for the question of "acceptable distribution of income" or "vertical equity".

One way to make the point I am trying to make is to refer to Figure 1. Here we have three different households' demand functions for public collection and disposal. Under System A, in which there is a zero charge for the service, the three households all offer the same quantity of waste, 4,000 units per year. However, their demand curves have very different elasticities, so that if a user charge of $.03 per unit is imposed they respond in very different ways. At the $.03 price, for example, C's elasticity is unity, D's is 1/3, and E's is zero.

If for simplicity we accept consumer's surplus analysis, we see that the households' loss of surplus generally is not correctly estimated by an amount equal to the new price, $.03, times the quantities offered at the original position. The impact as measured in that way is $120 for each household, but that is the true loss of surplus only for Household E. The $120 figure overestimates D's loss of surplus, which is only $105, and C's loss which is only $90. This is an obvious and simple point, and needs no belaboring here. It is an example of the familiar principle that one must not be content with an analysis based on "marginal" changes when the changes are actually quite non-marginal. This point is especially relevant in the present context, for when user charges are introduced for the first time they will be decidedly non-marginal!

In order to use this analytical point in equity analysis, one must of course make some conjectures on how the elasticities vary with income levels, and how they vary across households who are at the same income level, or who are in the "same circumstances" from the point of view of horizontal equity analysis. There are hardly any good studies on the price elasticity of

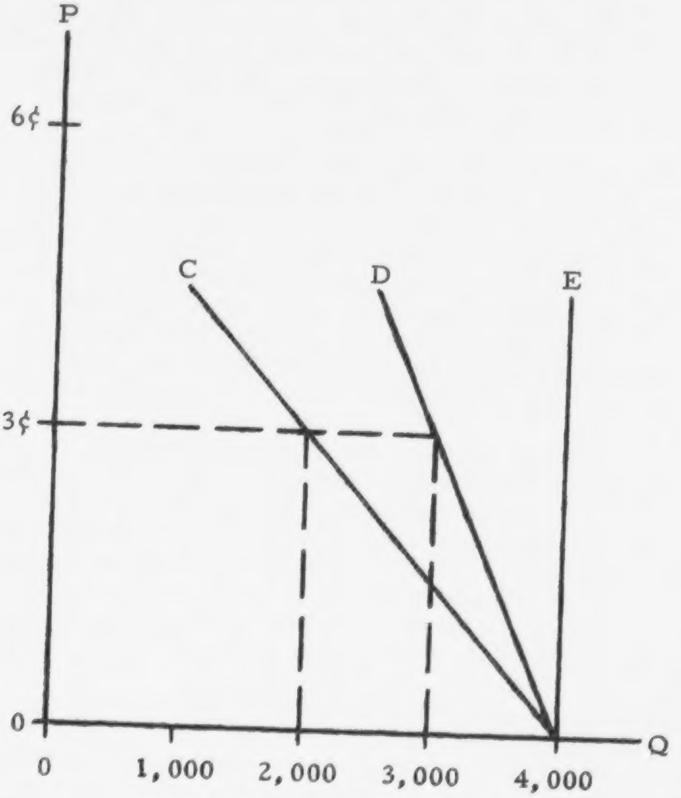

Figure 1

demand at all, let alone studies on how it varies in those ways. One would expect, however, that it does vary considerably across households at the same income level. How the elasticity varies with income is a difficult question. For example, higher income households probably have stronger preferences for some market goods and services which generate a lot of waste--packaged foods, newspapers and magazines, and large well-kept lawns, for example. And they probably have stronger preferences for a tidy household environment as well. And they are more likely to have higher opportunity costs of time, at least if we consider the adult members of the family. These all would seem to make their demand less elastic. On the other hand, they are more likely to buy compactors and kitchen garbage disposals, which would work in the opposite direction.

THE MEANING OF EQUITY

It is customary to speak of horizontal equity and vertical equity. The first is said to require equal treatment of persons in equal positions; the second to require equal taxes for equal abilities to pay, which most politicians accept as requiring some progressivity relative to income.

If we have a genuine public good, or at least a good with such pervasive positive externalities that the benefit theory of taxation can be disregarded, there is perhaps a simpler way of expressing the two principles. Then it is simpler to say there is only one principle: equity requires the equal treatment of persons in equal positions, but "equal positions" must in fact be determined with reference to equal ability to pay and "equal treatment" implies something like equal sacrifice. From the one basic principle stems both the horizontal equity and the vertical equity principle. Horizontal equity means requiring persons with the same index of ability to pay and in the same general circumstances to pay the same tax. Vertical equity means requiring persons, with different indexes of ability to pay, to pay different taxes, and a generally accepted implication of this is that as income increases, taxes should increase as a proportion of income.

This is overly simplified, but seems to me to capture the essence of generally accepted notions of equity in taxation for public goods. But in passing it must be admitted that the notion of "equal circumstances," when circumstances include aspects other than income or other index of ability to pay, is a slippery one. I have suggested earlier, for example, that certain family characteristics will affect the responses of households to user charges. Family characteristics affect the opportunity cost and psychic cost of the time required for aternative diposal, and also the ability to finance compactors and garbage disposals. While the incomes of households are important determinants of these impacts, the impacts are not perfectly correlated with income. Thus, different families may feel widely different effects of user charges, even though they have identical incomes. For example, a family with several young children or a nonworking spouse, who can handle the rubbish, may feel the adverse effects of user charges much less than another family with equal income but different circumstances. How is that to be evaluated in equity analysis?

This discussion has been for the case of public goods. When the public service is a business-like one, and the benefits and public sector costs vary considerably from household to another, we might abandon the previous notion of equity and substitute the principle of benefit taxation. We are especially likely to do so for a function like solid waste management, where the service is so business-like that it is left to business to provide in many places! And where the price needed to cover costs is such a small—almost trivial—proportion of total income.

The benefit theory means that the recipients of SWM services, should pay in aggregate a sum equal to the total costs of the services (this may require a multi-part tariff pricing scheme in order to preserve marginal-cost pricing). In addition to this aggregate requirement, it requires that the *distribution* of payments across households be the same as the distribution either of benefits received or of the public sector costs incurred.

Now, *efficiency* requires that the payments required of a household be based on the public sector *costs* incurred to serve it. However, here as elsewhere in economic policy, efficiency is not necessarily the only goal. The distribution of *benefits* from the public activity is a relevant equity consideration; if the SWM benefits were larger, relative to total economic welfare, we might pay a lot more attention to their distribution than we do. But the benefits are not very large--not nearly on the same scale as education or medical care, for example--so we are much less interested in sacrificing efficiency in order to get a more equitable distribution of them.

The benefit principle leaves no room at all for vertical equity in the case of something as small in scale as solid waste management. Or so it seems to me. If we didn't have to worry about the externalities from alternative disposal, we wouldn't need to talk about benefit principles of *taxation* at all. We could simply talk about business *pricing*.

However, not every observer will accept the benefit principle. The principle tends to be most appealing to those who believe firmly in the desirability of the so-called Musgrave-Tiebout "layer cake" model of government (8, referring to 11,17). In that model the functions of governments are sharply divided into the allocative, distributive, and stabilizing functions, and they are divided up among the *levels* of government, in a federal or other multi-level political system, so that only the lowest level handles an allocation function like solid waste management. In the model, SWM services are properly financed by the lowest levels because their externalities are not widespread geographically. Furthermore, those levels finance such services without regard for distributional consequences. They leave distribution to the higher levels of government, which redistribute income in general way, rather than through price subsidies which distort the efficient allocation of resources.

Not everyone accepts the layer-cake theory. Some critics would argue that the distributional consequences of *every* government policy, even one as mundane as the management of the garbage, must be considered explicitly by the level of government to which history and political realities have left the function. The critics would argue that no local government can assume that higher levels will in fact redistribute income in the desirable *direction*, let alone in the desirable, non-distorting *way*. They may argue that Thurow's notion of "individual-societal preferences" (16), or Tobin's notion of "specific egalitarianism" (18), both of which are originally put forward for goods looming as large as medical care and education, can be legitimately extended to solid waste. They may claim that the externalities of SWM are in fact pervasive enough that it is close to the public good end of the continuum. A related argument is this: in our modern technologically advanced society, the environmental media are so interconnected and the production of packaging materials is so far beyond the control of the individual consumer, that the management of waste is in fact an essential function for government and it is no longer realistic to expect individuals to feel any responsibility at all it. These arguments, while they are not likely to be accepted by many of us, and while the last one in particular is quite pernicious, are not totally ridiculous in the politicial arena.

REVIEW OF EMPIRICAL STUDIES

The sensitive and broad-minded solid waste manager will want to know something about all the changes in the distribution of benefits when he moves from management system A to management system B, even if in the end he risks a judgment that some effects are not awfully important. And from what I've said, it should be clear that he will want to know about all the changes in conditions of waste mangement, which accompany or are induced by the move to user charges.

The ideal empirical study for him would be a "before-and-after" study in some community similar to his own. Alas, he is unlikely to get such a quasi-controlled experimental result. At the moment, the best he can do is to look at the few studies which relate quantities of refuse offered for public collection and disposal to income and other household characteristics, under one single existing management policy. In other words, he will have to be content for now with analyses of the variations in so-called "demand" for refuse services under only one system, which corresponds to System A in our hypothetical comparison. He will find a few such analyses, but unfortunately they tend to be silent on some of the things which might actually happen when System B is substituted for System A. From them he will have to make his own conjectures on households' elasticities of demand for public service and how the elasticities vary with income levels and other characteristics.

I shall review the salient features of some of the major empirical studies here. In this, I am especially concerned, of course, with the estimates of the income elasticity of refuse generation, as that is very important in inferring vertical equity effects. There is a strong consistent pattern to the estimates of income elasticity. In addition, for horizontal equity, we must note *how well* any statistical demand function fits the behavior of households. The more poorly it fits, the more variation in refuse generation there is, at given levels of household income and other variables measuring "equal circumstances." That implies something for horizontal equity. However, rather than review all the details of the studies in that respect, let me say here that the statistical functions fit well enough for us to be confident on the income elasticity of demand, but also poorly enough to indicate that horizontal equity would be seriously violated under a financing scheme which collected the same amount from all households at the same income level, regardless of the refuse they generate.

Downing

Perhaps the most useful study which confronts equity aspects empirically is the one described in two papers by Paul Downing (5). Downing analyzed variation in refuse quantities, collection costs, and estimated property tax burdens across 64 collection routes (henceforth CR's) in Riverside, California in 1971. First, he estimated average volume of refuse per household in a CR, as a function of average family income, average family size, and land area per household in the CR. Volume was based on one single pickup in each CR during February or March 1971. We know that generation of refuse is highly seasonal, and the income elasticity varies considerably by season, at least in other parts of the country (2, 14, 15, 19), and Downing in fact recognizes that his results cannot easily be extrapolated to other seasons and/or localities. The income elasticity in the equation was .39.

That income elasticity is a "net" or "partial" elasticity, in that the equation holds constant other household and CR characteristics. As I have pointed out elsewhere (2, p. 3), in an analysis of income distribution effects, the "total" or "gross" elasticity, not holding other variables constant, is more important. If income and refuse quantities/costs are correlated, that is relevant even if other variables, correlated with both income and refuse, improve the fit of a statistical demand equation. Although Downing does not explain this point very well, presumably the gross income elasticity in Riverside was .55, for that is the value he uses later in discussing income distribution effects.

Downing's average income measure for each CR had to be constructed from Census estimates for Census Tracts for 1970. CR's are not coterminous with Census Tracts, so he had to construct a weighted average of the Tracts in each CR, weighting each Tract by the number of households living in the part of the Tract within the CR. This is apparently the same method used in the Kemper-Quigley and Tolley studies reported on later. Such an estimate is valid, of course, only if Tracts are geographically homogeneous. However, there is ample evidence that Tracts are not very homogeneous as far as income is concerned.

Downing then analyzed the variation in collection cost across CR's. He estimated cost per household per year on the basis of careful studies of labor requirements and user cost of equipment. In a regression, he found cost to be a function of refuse per household (based, again, on the one observation per CR in February-March 1971), truck travel times per household (to capture effects of density), and percentage of housing units which are single family. All these variables had positive and significant effects.

Downing added to collection costs estimates for costs of transportation and disposal at landfill. He then regressed total management cost incurred to handle a CR's refuse on family income in the CR; the estimated income elasticity was .44. Thus, if a user charge were imposed, and fell on households in proportion to the costs of handling their waste, it would have an income elasticity of .44.

An analysis of the impact of the alternative financing scheme, the property tax, requires estimates of the property tax payments by households in each CR. Downing first computed property values in each CR from 1970 Census block data. He assumed that the incremental property tax for refuse management would fall on each CR in proportion to the property values. Fully recognizing the shortcomings of many of his procedures, Downing then regressed estimated property values against family income, and found an elasticity coefficient of 1.16; that indicates that the property tax is progressive, and that the elasticity is well above what the elasticity would be for user charges based on management costs. Thus, Downing concluded that user charges would be much more regressive than the property tax.

Remember that Downing found the income elasticity of volume of refuse collected was .55. Accepting this as a measure of benefits, he concluded that the user charge would distribute costs in about the same proportion as benefits, because .44 is very near .55. The property tax method, however, has a net effect which is progressive, in the sense that tax costs to households are more progressively distributed than benefits (1.16 is higher than .55), and also in the sense that tax costs to households are more progressively distributed than would be user charges (1.16 is higher than .44).

Kemper-Quigley

One of the most prominent of studies is that by Kemper and Quigley (7). They analyzed New Haven data on weight of annual household refuse and family income estimates for 33 residential collection routes in New Haven, Connecticut, in 1972. They tried a variety of econometric specifications, using income and other variables to explain the variation in refuse generation per household across collection routes. The estimates of gross income elasticity of quantity varied with the specification, but were generally between .65 and .75 for the better fitting specifications.

For example, in a linear equation, the gross elasticity was .45 (income is the only independent variable), and the net .35 (household size and density also in the equation). However, log-linear equations fitted the New Haven data slightly better, and in those the elasticity rose to .82 when income alone was used, and to .67 when household size (significant) and density (not significant) were added.

In alternative models for the New Haven data, they used refuse per capita as the dependent variable, rather than per household, and personal per capita income as the independent income, rather than household income. In the log-linear versions of these, gross income elasticity was .39 and net .32. The estimates in linear forms were almost exactly the same. Household size was not significant in these regressions; density was significant in the linear form but not the log-linear form.

Kemper and Quigley also analyzed a pooled sample, consisting of the 33 New Haven routes plus municipality-wide data for 35 other municipalities in Connecticut. There was considerable measurement error for the 35 municipal observations. The degree of fit was very much smaller. The estimates of income elasticity were .65 (gross) and .51 (net) in a linear equation in which household size and density were not significant, but had t values above one. In the log-linear form, income was more significant than in the linear form, and gross elasticity was .67 and net .45. Household size was significant.

On the equity issue, Quigley and Kemper note that the total amounts are small in any event, perhaps only .3 percent of median family income for their sample of Connecticut towns. Their analysis, however, does provide "strong evidence that lower income households generate less refuse than higher income households" (7, p. 89). That pattern can be compared to existing estimates of the incidence of the property tax nationwide in order to conclude something about equity. As I explain in the next section, the authors accept some traditional estimates of property tax burden, which show it as very regressive; Kemper and Quigley note the older estimates give elasticities of property tax burden which are even lower than their estimates of refuse quantities. They conclude, therefore, that the property tax financing of residential refuse collection is much more regressive than a system of user charges which is based on quantity collected. They conclude that it would be "highly progressive" if cities went from a property tax to user charges based on tonnage. Thus, they disagree sharply with Downing.

It should be noted that Kemper and Quigley did not attempt to estimate the income elasticity of the cost of collecting refuse. This is in spite of their having accumulated vast amounts of data on collection cost by collection route, and analyzed it in other connections. It would have been most interesting if they had estimated a relationship between cost and income in CR's.

Chicago Study

I note two other empirical studies here. They are "demand" studies, which go into considerable detail on the variation in refuse weight or volume by income and demographic characteristics of collection routes. But they do not match this information with estimates of the income distribution effects of various financing schemes in the sample cities. Therefore, they are relevant here only because they give solid additional support to the conclusion that the income elasticity of refuse generation is well below unity.

The study of Chicago's 50 CR's by Tolley, Hastings, and Rudzitis (19; this is an updated version of a previous study by Sheaffer and Tolley, 14 and

15) is especially important, because it analyzes generation at different seasons. It also includes some variables which other authors have not, such as race and variance of household income in a CR. In the specifications which the authors feel are best, net income elasticities varied between .38 and .66, depending on the season and the exact specification, and gross income elasticities varied between .50 and .64. The elasticities tend to be highest in the fall and late fall/early winter, lowest in mid-winter (February), and lower in the spring and summer than in the spring and the fall. From this seasonal pattern, the authors conclude that there is a "basic, year-round volume of wastes, represented by the mid-winter volume, that is relatively less sensitive to income than 'excess' volumes in other parts of the year, except possibly mid-summer" (19, pp. 88-89). In this, they reinforce the earlier conclusion of Sheaffer and Tolley (14, 15).

This is an unusually rich and sophisticated demand study. I cannot go into more details here, however, because it does not confront the equity issues empirically.

Springfield Study

Finally, I may note my own unpublished study of refuse generation demand in 1972 in Springfield, Massachusetts (2; see also 3). My analysis of the city's 20 collection routes attempted to explain variation in refuse by variation in several social and demographic variables: property value per household; percentages non-white, younger than 18 and older than 62; and percentage of housing units occupied by their owners. These functions fitted rather well, except in the winter season. I made no effort to construct income estimates for CR's, having less faith in the homogeneity of Census Tracts than Downing, Kemper and Quigley, and Tolley. However, I constructed indirect estimates of gross income elasticity in the following way: (a) I estimated refuse demand equations using CR's as units of observation, as noted above; (b) I then assumed that the same demand function would apply if Census Tracts were the units of observation, and used the function (based on CR's) and the observations on independent variables (by Tract) to estimate the refuse generated in each Tract; and (c) I then regressed those estimates of refuse quantities on income in Tracts to get a gross income elasticity. The results varied by season: .17 in winter; .44 in spring and also in summer; and .72 in fall (the fall elasticity is high obviously because of all the New England leaves falling on the large lots of higher income neighborhoods).

I had no direct data on costs, and did not engage in the same useful exercise of estimating them carefully, as did Downing and Kemper and Quigley. I resorted to very rough estimates of relative collection costs in each area. To do this, I assumed that in a CR, the collection cost per household relative to the city average, would be the same as the relative number of standard collection crews required to service the CR in each season. Each crew consisted of the same number of men and trucks, so I felt able to assume the collection cost in CR's varied in proportion to the number of crews. By assuming this, I estimated an elasticity of collection cost per household with respect to refuse per household: .79 in winter, .75 in spring, .81 in summer, and .63 in fall. When I multiplied those by the elasticities of refuse quantity with respect to income, previously estimated, I got these estimates of elasticity of cost per household with respect to family income: winter, .13; spring, .33; summer, .36; and fall, .46. While my cost data fell far short of the quality of Downing's, they are consistent with his results, and extend them to other seasons: the cost of serving households on a route rises much less than proportionately to family income on the route.

I did not attempt to estimate the pattern of property tax incidence in Springfield. But I concluded that the property tax elasticities are at least a bit higher than the refuse elasticities just given. Therefore, I concluded that if Springfield refuse and costs data were typical, one could say that "the use of property taxes to finance refuse management may have a very slight equalizing effect on the income distribution" (2, p. 2).

IMPORTANCE OF ASSUMPTION ON INCIDENCE OF PROPERTY TAX

The most likely alternative to user charges for financing SWM is the local property tax. Thus, what one assumes is the incidence of that tax is crucial for his analysis of both horizontal and vertical equity effects of substituting user charges for it. That was shown by the conclusions of the Downing and Kemper-Quigley studies referred to in my previous section. The authors reached different conclusions on the distributional impact, not because they assumed very different income elasticities of refuse collected, but because they assumed radically different income elasticities of the property tax burden. Therefore, I think it useful to delve into the theory and literature on property tax incidence as part of a discussion of the equity considerations in SWM.

I have dipped into the voluminous literature on property tax incidence several times, and I tried to refresh my knowledge of it in writing this paper. We all know there is a "New View" on this, which argues that even the residential property part of the tax is much less regressive, and may even be slightly progressive, than the conventional wisdom of 10-15 years ago. I think it is generally agreed by now that the New View is sound enough to force a major revision of thinking, although not all are so bold as to insist that the tax _is_ regressive or _is_ progressive. Note that by "New View" here I am not referring to the abstract theoretical literature which argues that the property tax is _highly_ progressive under certain artificial assumptions. There is such literature, but by New View I mean rather the Aaron-Netzer-Mieszowski theoretical and empirical studies which amend the abstract theory in applying it to the real world (1, 13, 9, 10).

Such a champion of the older conventional wisdom as Dick Netzer has partially recanted his earlier position, and now agrees that the residential property tax is not as regressive as once thought, and that the total property tax is probably slightly progressive in a typical jurisdiction (13). I may add that Kemper and Quigley appear to have relied much more on Netzer's earlier position, and on other writers using the same assumptions, than on his later change-of-mind and other representatives of the New View. (Netzer's earlier study was (12)).

Netzer's partial recantation is such a useful review of all the arguments that I have relied heavily on it in structuring my own discussion here. What he is most convincing on is that the whole subject is incredibly complicated, and that it is rather misleading to speak of "the" property tax in a "typical" jurisdiction. However, I feel the following remarks represent fairly the opinion of the majority of public finance economists at this time.

1. First, under either the older view or the newer one, the residential property tax is more regressive or less progressive than the nonresidential property tax. Netzer takes pains to argue that the residential part is still probably regressive in a typical jurisdiction, with an elasticity of property tax burdens with respect to income of about .7, even though the other parts of the tax and the tax as a whole are proportional or slightly progressive. Thus, we have at the start a problem of context: is it the residential tax or the general tax which is the alternative to user charges? Clearly, it depends on the jurisdiction we are studying. Most writers assume it is the residential tax which is the alternative, because SWM services are provided to persons living in housing units. However, I am sure that many jurisdictions cannot legally or politically change the residential tax rate without also changing the rate on other property. Over a period of time, of course, different assessment ratios for different kinds of property appear, whether legal or not. But ratios would not change merely because user charges are subsituted in one public function; namely, SWM. Thus, at the margin, it appears that in some jurisdictions the decrease in tax rate would have to apply to all property.

2. Neither the residential part nor the total tax is as regressive as the conventional view of 10-15 years ago suggested it was. This point needs elaboration in depth, and I return to it later.

3. Strictly speaking, there is no such thing as "the" property tax. The tax is levied at widely different rates, and the differences per se are relevant for incidence theory. Even within a jurisdiction, some property is exempt, and in addition the rates differ greatly across jurisdictions. The jurisdictions differ in the possibilities property owners have for shifting the tax. This means the best analysis is one which is tailor-made to the jurisdiction. It must allow for characteristics such as assessment practices, possibilities for tax exporting (shifting to other regions) by the industries whose capital is taxed, the elasticity of substitution between capital and other factors in those industries, the ratios of market value to annual rent in each housing market, the competitiveness of the rental housing market and the kinds of individuals who own rental housing units, and many more.

4. The conclusion on incidence depends greatly on whether one adopts annual income or a longer-run, "permanent" income as the income measure. The tax is less progressive or more regressive, the shorter the period for which income is measured. The New View contains as one crucial element a conviction that a longer-run measure is more relevant.

However, if one adopts so permanent a concept as lifetime income, the question becomes complicated by the fact that many families move from jurisdiction to jurisdiction several times in a lifetime, and some of them move each time from a lower tax base base (per capita) community to a higher tax base (per capita) community. Thus, even if the tax is progressive for all the families living in a jurisdiction at any one time, it is possible that over a whole lifetime the tax price of local services rises much less slowly than income. Some who push this argument point out that many of the poorest families are confined for their entire lifetimes to central cities where tax bases are low, tax rates are high, and public services are poor. However, even if multiple jurisdictions in a lifetime are important in analyzing the property tax as an institution, I don't think they are very important in analyzing the changes in tax rates in any one jurisdiction.

Along the same line as the multiple jurisdiction point, Hamilton has suggested that the property tax ultimately is far more regressive than any cross-section evidence on incomes and estimates of tax burdens can suggest (6). That is because the property tax is part and parcel of a comprehensive system of local finance in which restrictive zoning is used to limit high tax base communities to high income individuals. He hypothesizes that the restrictive zoning, which is employed by affluent communities precisely because they must rely heavily on local property taxes to provide services, raises the price of housing in poor communities. This adds significantly to the impact of the property tax payments *per se*. This argument probably should be ignored in our present context, which is the financing of a single function which does not absorb much of the local budget. In other words, changing the financing of SWM will not in itself have much impact on the system Hamilton is describing.

With these summary conclusions as background, allow me to sketch the basic theoretical arguments. Under the old view, the tax decreases the returns to capital and land in the short run. In the long run, the supply of land is inelastic, so the rate cannot be restored by any shifting of land out of taxed uses, if the tax is general. Therefore, the land tax is borne by landowners, which means it is quite progressive. But the supply of reproducible capital has some elasticity in the long run, and the owners of taxed capital will shift the tax at least partly on to consumers, and perhaps other factors, by reducing the quantity supplied until the gross return rises enough to restore the net return to equality with other investments. In the end there is some fall in the net return to capital, but the lion's share falls on consumers of goods and services, and disproportionately on housing, a very capital-intensive good. As the elasticity of general consumption with respect to current income is below one, and the elasticity of housing expenditures well below one, the tax on reproducible capital is seen as regressive and the residential property tax especially so.

The New View comprises two parts. First, the theoretical derivation of the incidence of a general tax at a uniform rate on all capital and land; second, the adjustment of the theoretical results to allow for the fact that the tax is not actually levied on all capital, and not at a uniform rate on the capital which is taxed.

A key assumption in the New View is that the supply of reproducible capital to the economy is inelastic, even in the long run, just as is the supply of land. In that case, a general and uniform tax on capital must fall on the owners of capital. The inelasticity of supply eliminates the possibility of shifting the burden to consumers or to other factors of production. As the earnings from capital are concentrated in the higher income groups, this means the tax is quite progressive.

In the real world, the tax is not uniform. Some capital is taxed at much higher rates than other capital, partly because of intra-jurisdictional variation and partly because of inter-jurisdictional variation. The owners of capital which is taxed at more than average rates can -- and will -- shift some of the burden by moving their capital out of the high tax sectors and into the low or zero tax sectors; that will raise the prices of goods and services produced using the heavily taxed capital. The more uses of capital are taxed, and the less the variation in tax rates, the less of the burden can owners shift off themselves. Of course, the process will result in lower prices for goods using less heavily taxed capital. To the extent there are such shifts forward on to consumers, the incidence of those excise-type effects will depend on how the consumption of various goods and services varies with income. Some backward shifting is also possible, as the restriction of capital in some industries and some localities may reduce the demand for that labor which is relatively immobile and must accept reduced wages to gain employment. However, these backward shifting effects are probably quantitatively minor compared to the forward shifting or excise effect.

Housing is very capital intensive, and the property tax rates on capital in housing appear to be higher than average. That means the excise effect will raise the price of housing to a significant degree. From a practical standpoint, housing is probably the most important good the price of which is raised or lowered by the excise effects of differential tax rates. The fact that the price of housing does rise, therefore, is a central fact under the New View, just as it was under the older view; however, the New View stresses that the rise will be less than formerly thought, because the fairly widespread taxation of capital and the presumed inelasticity of supply reduces shifting. Furthermore, the same process of forward shifting which increases the price of housing will reduce the prices of lightly taxed goods, the consumption of which may be roughly proportional to permanent income. For consumers as a whole, this may offset the housing effect.

Break has concluded:

> "Property tax burdens on consumers ... are probably less important than commonly supposed. They are a function only of interregional and intraurban tax differentials and not of the total property tax rate; the excise tax effects generated by those tax differentials contain labor and landlord burdens which reduce the pressures making for consumer burdens; and such national consumer burdens as do

> exist fall not on consumers in general but only on those with relatively strong tastes for the output of the industries that are more heavily taxed than others." (4, p. 165.)

The New View not only has a different conclusion on the extent of forward shifting, it also has a different concept of income. It favors a "permanent" notion of income, rather than a single year's income. The empirical studies of housing demand show that the elasticity with respect to permanent income is considerably higher than the elasticity with respect to annual income -- it is perhaps unity or even slightly higher. Thus, even if housing consumers paid all the residential property tax, it might not be regressive!

Somewhat strengthening this conclusion is other empirical evidence that the housing market produces ratios of market value to annual rent which rise with income. If the annual rental is proportional to permanent income, the value then rises more than proportionately. If the property tax is proportional to value, then the tax rises more than proportionately as well.

Thus, the New View has several strings to its bow. The widespread taxation of capital limits the shifting by capital owners; the income elasticity of housing expenditure with respect to permanent income is around unity; and the value of property, which is the tax base, rises with income even faster than housing rental expenditures. And even if there is a regressive housing effect, there are some offsetting effects for the average consumer from lower prices for other goods and services.

Against these there are some counterarguments, a few of which have already been mentioned. The housing occupied by lower income families may be systematically overassessed, which offsets the value-rent ratio phenomenon. Many feel the permanent income is not a solid enough empirical concept on which to rest a policy decision. Others accept the permanent income concept, but feel that if properly extended to lifetime income it points to regressivity; this is the multiple-jurisdictions-in-a-lifetime phenomenon mentioned earlier. Another consideration is the possibility that much rental residential property is owned by low and middle income families, who rent out parts of their own homes or who rent out at most one or two houses. If rental property owners are lower income people, and their tenants are also lower income people, it doesn't matter how much of the property tax on the property is shifted forward and how much reduces the net returns to owners. Finally, the deductibility of property tax for Federal income tax purposes means that the net impact on higher income owner-occupiers is reduced. One's feeling on how important this is depends on whether he thinks the deductibility feature should be analyzed as a feature of the property tax or as a feature of the Federal income tax. It is true that a change from the property tax toward user charges will have a blunted favorable effect on high income families because part of the reduction in property tax will be offset by higher Federal income tax. In an empirical analysis, one must remember the very recent trend toward raising the standard deduction and reducing the number of Federal taxpayers who itemize deductions.

By now, if you have never gotten into this literature before, your head may be swimming. If you have gotten into it, your head may be swimming anyway, for you may be nagged by still additional considerations which I have not had time to mention. The safest conclusion, I think, is Netzer's: "There seems no substitute for empirical work that recognizes local differentials and perhaps, no case for the kind of nationwide estimates of incidence by income class that I and others have made in the past." (13, p. 519.)

However, if one does insist on generalizing from national studies to a particular jurisdiction, say a "typical" jurisdiction, one could conclude with Netzer that the property tax on the whole has an elasticity with respect to income of about 1.1 and the part on residential housing and consumer-owned durables an elasticity of about .7. Netzer makes these ball-park estimates on the assumption that income is measured as annual income, but with some modification at the lower end of the scale to raise incomes there above the ones reported as annual incomes. This modification is to allow for the fact that many poor people are elderly homeowners who have a high asset-income ratio, for the fact that some other poor people are poor only temporarily and also have comfortable asset positions or at least other reasons for higher income prospects, and for the underreporting by some poor people receiving public assistance.

CONCLUSION

As noted earlier, the empirical studies of the income elasticity of solid waste volume and collection cost produce estimates which are about equal or a bit lower than the Netzer guess on residential property tax burdens. It is unlikely that the income elasticity of solid waste is above unity. This suggests that the vertical equity of user charges and the residential property tax are not much different from each other. Indeed, it hardly matters anyway, because the dollar amounts are very small to start with. Therefore, there is no reason to fear any noticeable increase in regressivity from substituting user charges for the property tax, especially if it is the residential property tax which is being replaced.

Nor are there valid arguments, in my opinion, against user charges on grounds of "merit goods" or on grounds that society should want to redistribute income in a way dependent on poor persons' use of solid waste management services. As I have said earlier, I do not think we can apply to solid waste the notions which justify specific price subsidies on medical care, housing, and education. In fact, I would be prepared to argue the opposite, that persons should be encouraged, even at some cost in terms of efficiency, to take care of their own waste. Society as a whole should want to encourage habit of resource conservation, for one thing, and the price system in solid waste may be useful in this respect.

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PRICING MUNICIPAL REFUSE SERVICE: POTENTIAL EFFECTS ON MUNICIPAL BUDGETS

by

KENNETH L. WERTZ

I wish to examine how two approaches to pricing household's generation of refuse could affect municipal budgets. The local pricing approach contemplates a municipal charge system for residential service under which a property owner would pay more as he presented more standard containers of refuse for collection and disposal. The federal pricing approach would create specific excises against certain products used in the packaging of consumer goods and distribute the revenue to local governments to assist their financing of refuse service.

In the opening sentence I emphasized "could" because it connotes potential and uncertainty of result. The budgetary impact of a pricing program depends not only on the responses of households but also on decisions made by municipal officers. So long as the dollar amount is not trivial, the introduction of a new component of revenue creates the leeway for managerial discretion and may quicken the propensity to use it. I cannot predict the specific responses (and their budgetary images) of municipal officers who operate under heterogeneous conditions in the nation's 18,517 municipalities, but I do endeavor to describe what the opportunities might be. I utilize many approximations to suggest the order of magnitude of certain effects, and indicate the method of calculation in the event others care to employ alternative estimates.

The first section looks at the revenue side of the budget, and the second at the expenditure side. A final section concludes with a bit of speculation.

REVENUE SIDE

The revenue yield of a pricing system depends on the charge structure, the height of the charge, the base to which it applies, and the reactions of consumers and producers. With a federal program there is additionally the matter of how revenue is to be returned to municipalities. For concreteness assume that a municipality's total revenue from a pricing system, whether locally or federally administered, just equals what the municipality was previously spending for residential refuse service. The basic question for municipal officers is whether these receipts will be allowed to change the total amount of local governmental revenue from own sources that had previously been planned for in preliminary budgets. The polar possibilities are that charge receipts are treated as an addition to own revenue or are used to fund reductions (or to defer planned increases) in local tax rates.

If own tax reduction is chosen with the intent of holding constant total local governmental revenue from all sources, then municipal officers must plan on reducing own tax revenue by an amount that is less than anticipated charge receipts. This is so because some intergovernmental transfers, of which local governments are the net beneficiaries, are allotted according to formulae that reward a local government for collecting tax revenue but not charge revenue. A universal case in point is the federal general revenue-sharing program. To a first approximation, the grant to a unit of local government varies directly and proportionately with the magnitude of its "adjusted" tax collections. Thus if a municipality were to replace X% of its own tax collections with charge revenue, its federal revenue-sharing grant would decline by X%, other things being equal and assuming that the municipality's allotment is not determined by the provisions governing maximal and minimal allotments. A rough estimate is possible for the aggregate of municipalities. In 1975 all municipalities combined raised $21.1 billions in own taxes and $3.6 billions in miscellaneous own general revenue, of which $3.6 billions were spent for education (municipal expenditures for education were actually $7.2 billions in 1975, but only 49% of local governments' expenditure for education came from own sources). Thus "adjusted" taxes -- the adjustment excludes revenue raised for education expenditures -- were about $21.1 billions. If we take municipal outlays for residential refuse service and financed from local general revenue to have been $1.2 billions in 1975 (actually, $1.8 billions was spent for "sanitation other than sewerage," but some of this was not for residential service and some was not financed by own taxation), then its replacement by an equal amount of charge revenue would have implied a reduction in revenue-sharing grants to all municipalities of about 6%. The dollar loss would have been $125 millions, since all municipalities received $2.2 billions in federal revenue-sharing payments in that year. The calculation indicates that on average a municipality could enact local tax relief of $.94 and lose $.06 in intergovernmental transfers for each dollar collected in charges, if total revenue from all sources is to be unchanged. These figures will differ from place to place, depending primarily on the budget share of public residential refuse service in a given municipality and on higher order interactions in the workings of the revenue-sharing formula.

For municipalities in some states even less local tax relief could be afforded because of state-local intergovernmental flows. For example, in 1973 the Michigan state government distributed $54 millions to local governments according to formulae that increased the share of any particular

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1. Outlined at Advisory Commission on Intergovernmental Relations, Federal-State-Local Finances, 1974, pp.79-81.

local government as the latter's own tax collections increased. Similarly, the North Carolina state government distributed $26 millions according to local property tax levies. Such programs[1] were also to be found in California, Ohio, and Wisconsin in 1973, and it is quite possible that their adoption has since spread in imitation of the federal general revenue-sharing program.

The discussion has so far regarded charge revenue as a source of local tax reduction, but it applies as well if charge revenue is meant to enlarge local revenue from all sources. When an extra dollar of revenue is raised through charges rather than taxes, the local government foregoes the bonus that higher level governments will pay on the latter.

EXPENDITURE SIDE

One obvious difference between a local and a federal pricing system is the incidence of the costs of running the system. S. 1281 (95th Cong., 1st sess., 1977) to my reading would erect no condition that should occasion signifcant municipal expenditure solely for the purpose of making the municipality eligible for the return of charge revenue from the federal government. A local pricing system, however, is sure to cause additional local expenditure for administration. It is necessary to have an account with each property owner; to publicize rates and information about standard containers; to bill, collect, and perhaps issue receipts; and to adjust disagreements about the correct charge. Although municipalities have already opened accounts for purposes of property taxation and although they could economize by combining billing with tax or public utility billing, extra work and extra expenditure must still be expected. Furthermore, it is necessary to observe and record the number of containers emptied at each property. This task involves additional expenditure too, for such data are not compiled where general revenue financing is employed.

There is nothing incorrect about this fatiguing recital of conventional wisdom. But it takes too narrow a view of "administrative costs" by ignoring what they could buy. One return on the costs of running a local pricing system is the regular collection of data which might be used for the more efficient supply of service. The quantitative importance of this potential is unknown, but the state of municipal recordkeeping that researchers have encountered is at the very least suggestive that that potential remains largely unrealized. Microdata on refuse generation would make it possible to search thoroughly for cost reducing route designs and factor assignments. Aggregated and kept over time the data could be used to sharpen planning for capital expenditures, manpower adjustments, disposal site acquisition, and adjustments to seasonal variations in refuse generation. Efficiency savings from these sources, assuming that they are realized through managerial action, are properly considered as offsets against the direct cost of operating a local charge system. The federal product charge system generates no comparable information, and no comparable efficiency savings should be expected.

A second type of return on administative costs is an intangible that appears in no governmental budget, even though much public spending and revenue raising are undertaken in its name. The intangible is equity. The content of the term changes from one application to the next, and unanimity about its proper content in any one application is rare. These realities understood, we may note that some of the enthusiasm for pricing proposals is based on the view that a person ought to pay for service in proportion to the costs which his refuse generation visits upon the public treasury. The regular satisfaction of that norm under local tax financing, which is essentially property tax financing, is just not in the cards: The connections between determinants of refuse generation and property value and the connection between assessed value and property value are too irregular. How the burden of local taxation for refuse service might be distributed is scrambled another turn by the deductability of local property taxes (but not charges and then only for itemizers) from the federal (and many state) individual income tax base(s). A local charge system, on the other hand, is predicated on a clear and direct connection between payments made and costs imposed, from one person to the next, provided that the logic of the system is carried out. Administrative costs for running a local charge system are then costs of producing horizontal equity. "Local" is emphasized because the same results are unlikely to follow from a federal product charge system that returns revenue to local governments on a capitation basis.[2] No systematic relief from current inequities can be expected if municipal officers utilize their federal grants for improved refuse service (as contemplated by S. 1281), because neither the magnitude nor the distribution of local taxes would be affected, and they are the putative sources of the inequities. Some systematic relief would occur if municipal officers were instead to utilize federal grants to fund reductions in local taxes. But in either case federal pricing would create new variances between payments made and costs imposed, because product charge collections are based on refuse generation while the return of revenue is based on population, and considerable variance appears to exist in per capita rates of generation from one place to the next.

In summary, the potential for efficiency savings from data availability and an improvement in horizontal equity are direct offsets against administrative costs of managing a local pricing system. It is not possible to arrive at a monetary figure for net administrative costs, because one of the products is an intangible and will be valued differently even by persons in the same locality.

The collection and disposal of refuse is the second major area where pricing is likely to have a noticeable effect on the expenditure side of municipal budgets. Federal pricing would create a private marginal cost against one's generating extra refuse. Local pricing would create a private marginal cost against one's presenting extra refuse for public collection. Local tax financing of service does neither. Hence pricing, relative to the status quo, would reduce the amount of refuse which the municipality would have to treat, and service with constant features (frequency, place of collection, etc.) could be supplied for a smaller municipal outlay.[3] Since the charge-induced reduction in operating costs is to be realized year after year, it could function as an endowment for programs whose budgetary impact would last over many periods. The cost savings could be returned to citizens through reduced local tax rates, distributed to municipal employees as higher effective wages, applied to providing refuse service of a higher quality, or applied to augment other municipal programs.

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[2] This position is elaborated at K. L. Wertz, "Equity Impacts of Proposals for Federal Product Charges," Journal of Environmental Economics and Management, Dec. 1977.

An order of magnitude estimate of the charge-induced reduction in operating costs is possible through a succession of approximations. I have elsewhere[4] instanced the fact that in 1970 per capita collections of residential refuse in San Francisco, where pricing is practiced, were 25% less by weight than the per capita figure for all urban areas combined, where pricing is very seldom practiced. This is a gross comparison; it does not adjust, up or down, for other possible influences on refuse generation. Let us stipulate a 20% reduction to follow from the introduction of pricing, the downward adjustment made because the height of the charge in San Francisco probably exceeds the average level that would be contemplated in other municipalities. The second figure that is needed is the elasticity of total cost of refuse service with respect to refuse tonnage. Barbara Stevens has produced estimates for collection costs that range from 0.8 to 1.0, depending on city size.[5] Let us use an intermediate value, 0.9, and assume that it applies to disposal costs as well. The conclusion, then, is that pricing could result in an 18% decrease in annual operating costs.

The significance of this figure in the aggregate can be better seen by carrying the approximation through a few more steps. Assuming that municipalities as a group are now spending about $1.8 billions per annum for residential service, an 18% decrease equals annual savings of $0.32 billions in 1978 dollars. Assume finally that the current municipal borrowing rate is 6.67%; that savings in operating costs are realized in perpetuity; and that both the nominal savings and nominal borrowing rate grow at the same rate as inflation generally. Then the present value of the charge-induced reduction in operating costs to all municipalities combined would be $4.8 billions in 1978 dollars. This is a large amount, but not an imposing one. It is, for example, only double the amount that all municipalities are now receiving in federal general revenue-sharing grants in one year.

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[3] The metering method which is employed under local pricing could contribute to savings in operating costs, independently of any charge-induced effects on the output of refuse. For example, if the use of standard disposable bags were required in lieu of conventional containers so that quantity for billing purposes is determined by the number of bags set out, then the costly return of empty containers from street to dwelling would be eliminated. Such possibilities are not considered in the estimates in the text.

[4] K. L. Wertz, "Economic Factors Influencing Households' Production of Refuse," Journal of Environmental Economics and Management," Apr. 1976.

[5] B. J. Stevens, "Scale, Market Structure, and the Cost of Refuse Collection," Review of Economics and Statistics, Aug. 1978.

The use of the foregoing analytical structure will probably lead to underestimates of the charge-induced savings in operating costs experienced by any one municipality in the event that a majority of municipalities adopts local pricing or that federal pricing is installed. It would then become reasonable to think of secondhand markets becoming more active and of producers taking the existence of charges into account when making decisions about packaging, two changes that would reduce the amount of refuse which a municipality collects and disposes of.

CONCLUSION: A RACE OF ONE?

A municipal officer who might have earlier considered the adoption of a local charge system could have framed the matter this way. "I get charge revenue, a modest reduction in operating costs, the likelihood of cost savings due to data generation, and much better satisfaction of a particular distributional norm. In return I incur a certain increase in administrative costs and the equally certain unpopularity of having proposed a new 'tax' (even if existing taxes were adjusted so that revenue collections from all sources were held constant)." However attractive this package might once have been, its attractiveness probably evaporated with the recent legislative advances of the federal proposals for product charges. From a municipal officer's perspective, or so I should think, the federal plan would have none of the liabilities of a local pricing system. Under federal pricing administrative costs exist but are essentially borne elsewhere. Responsibility for the enactment of a new revenue program can also be put elsewhere. The risk of increased littering that goes with local pricing is removed by federal pricing, and the risk of having promoted a bad idea--if in fact pricing fails to induce much reduction in the output of refuse--is shifted to other parties. Yet the federal plan would provide revenue and stimulate whatever cost-reducing decreases in waste generation there are to be realized. Only the potential efficiencies that arise from data generation and the increased equity in finance that are unique to local pricing need be given up. As witnessed in other intergovernmental aid programs, the prospect that the federal government may in the future bear the costs, broadly conceived, of providing many of the benefits that could be had by local action is probably enough to retard local action now. I suspect that the contest of pricing propoals is now a race of one.

SECTION 4

COMPARISON OF USER CHARGES AND PRODUCT CHARGES

"The Optimal Policy Mix for Solid Waste Pricing" (James F. Hudson).

"Fundamental Comparisons of Alternative Solid Waste Management Policies" (Allen K. Miedema).

THE OPTIMAL POLICY MIX FOR SOLID WASTE PRICING

by

JAMES F. HUDSON

INTRODUCTION

It would be difficult to claim a connection between the concept of "optimality" and the field of solid waste management, despite the title of this paper. The handout from our recent work for the Resource Conservation Committee, and other papers in this seminar, summarize the state of the theoretical and practical knowledge about solid waste management and potential pricing policies. According to these papers, there is little likelihood that we will approach a mix of policies which could be called "optimal", as defined by economists.

Still, it may be possible to locally optimize our policy choices, given the set of options which appear politically feasible. It is this more limited sort of optimization which this paper addresses. It describes steps which can be taken towards optimization, and it defines reasonable goals in this regard but stops short of determining some form of globally optimal policy mix.

This paper will ignore issues such as the assumptions behind the optimality of marginal cost pricing, the requirement for constant returns to scale, and the declining marginal benefit curve for pollution. Further, the paper will not repeat the descriptions of research contained in the handout, but rather will focus on the conclusions arising from the research, and the potential for policy improvements in the field of solid waste management. Although the conclusions reached in this paper are somewhat speculative, they are based on the author's experience in the field of solid waste pricing and management.

APPROACHES

There are two basic economic approaches which have been suggested for reducing the quantity of solid waste reaching final disposal; these are product charges and local user charges. Both act through reducing the amount of product-related wastes, and through increasing the amounts recycled. This paper will argue that, under a reasonable—at least to the author—set of assumptions, the interactions can be generally beneficial and conducive to achieving efficiency and equity goals. It will make arguments related particularly to the incentive structures of the various actors in the system, and the directions of their probable responses.

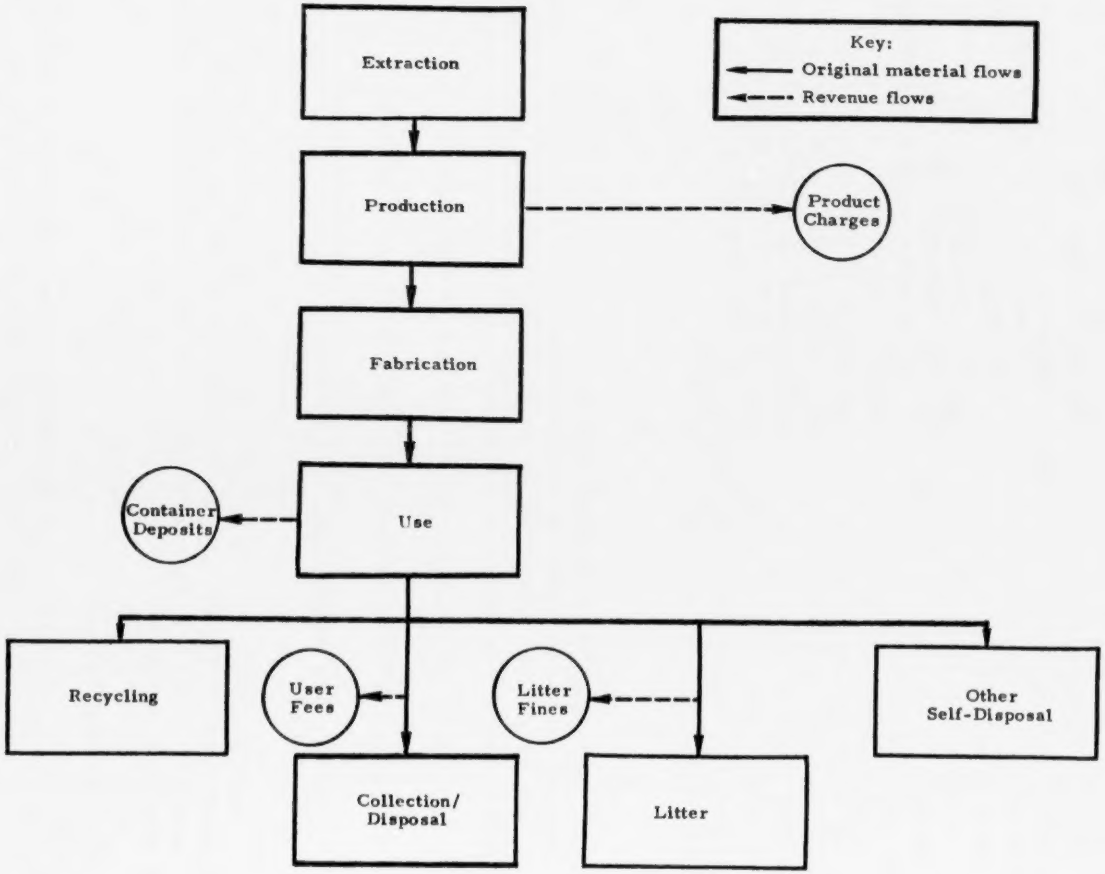
The effects of pricing policies are described schematically in Figure 1, along with the impact points of the charges. While this schema represents a simplification, it leads us to suggest a number of actors in the process:

- extraction firms;
- production firms;
- fabrication firms;
- wholesaling/retailing;
- households and other consumers;
- solid waste management firms and agencies;
- secondary materials retailers/wholesalers;
- state and federal governments;
- equipment suppliers for waste management.

Product Charges

Product charges act relatively early in the cycle, as described in the handout. They will reduce the level of output and revenues for extraction firms. This is intended to correct the inefficient or excessive output levels prevalent prior to the imposition of charges. There will be a direct incentive to increase the production and fabrication of recycled materials and/or to decrease the use of materials for packaging. Price increases will be passed on to consumers, leading to a loss in consumer surplus, which could be counterbalanced somewhat by reduced solid waste management costs. In addition, the product charge revenues will be distributed to local governments, to offset solid waste management costs, or increase the spending for other social services, leading to (it is hoped) a net benefit consumer surplus. The local solid waste management agency will be able to lower cost, and may receive revenue transfers from the system. Recycling firms at the wholesale and retail levels will see increased demand, and probably higher prices; current users of the wastes, however, will also have to pay higher prices for their goods.

In essence, the product charge provides revenues to local governments, increases the demand for post-consumer wastes, and provides an incentive for firms to modify their use of packaging, with bonuses for forms which minimize waste-handling costs.



Extraction
Production
Fabrication
Use
Product Charges
Container Deposits
Recycling
User Fees
Collection/ Disposal
Litter Fines
Litter
Other Self-Disposal
Key:
Original material flows
Revenue flows

Figure 1. Impact points of pricing options.

User Charges

User charges related to the quantity of waste may provide some incentive for consumers or firms to change their consumption patterns and to select products with relatively small contributions to the wasteload. The basic incentive is to reduce the quantity of waste placed for collection/disposal: there are a number of methods to achieve this. One method is to increase product lifetimes: this is likely to result in reduced consumption, with potentially significant effects on waste quantities. Other techniques include at-home recycling (such as composting yard waste); product recycling; littering (including disposal at workplace, etc.) and other forms of disposal such as direct hauling to the disposal site, or outside contracting. Inventory increases, for example of newspapers, are not going to affect total waste quantities for the long-term, though they may lead to change in the amount of collected waste.1 The handout suggests in Section 4.3 that it is relatively easy to achieve 30-50% reductions in wasteloads if yard wastes can be used on-site, and if recycling programs are available for beverage containers and newspaper. With user charges, recycling firms should see an increased supply of waste. Collection/disposal costs may go down; litter collection costs, on the other hand, might rise, depending on household behavior. The direct incentive of the charge is to reduce the quantity of wastes placed for collection/disposal.

MARKETS

There are two submarkets of interest in analyzing solid waste: the traditional production/consumption submarket, and the disposal/recycling submarket. We are primarily concerned with the operation of the latter, and the interactions between the markets, which occur through:

- transfer of revenues (e.g. product charges);
- changes in consumption caused by disposal practices;
- supply and demand for post-consumer wastes for recycling.

The disposal submarket consists of the household engaged in post-consumption waste disposal and recycling, the firms or agencies charged with solid waste collection and disposal, litter management, and the retailing of recycled materials.

ANALYSIS OF SYSTEM COMBINATIONS

To identify a desirable mix of policies, the effects of combinations of product charges and incremental user charges should be considered. These include effects on consumption, household income, levels of recycling (and prices for recycled products), operations of the extraction/production/fabrication firms, operations of the solid waste collection and disposal agencies or firms, and requirements for other forms of disposal.

Effects on Consumption

As mentioned above, the product charge is intended to have an effect on consumption, shifting the purchases of cost-conscious households away from heavily packaged products. The result should be a shift in consumption towards efficiency of at least the materials affected by product charges.

Because of the averaging that takes place in creating a can or bag of solid waste, and the low cost per item, I do not expect any change in consumption to result from imposition of incremental user charges. Product lifetimes may be increased somewhat, but I would expect this effect to be relatively small.

With respect to consumption, then, there may be some adverse interaction of the product charge and the deposit system, but this will be slight.

Effects on Household Income

With the product charge households will experience increases in prices with an effective loss in income somewhat less than the product charge payments (because of shifts in consumption). The distribution of this burden across households depends upon their consumption patterns.

Product charge revenues will be used to defray the administrative costs of the program, and to provide funds to state and local governments which will either be used for reducing solid waste disposal charges, property tax relief, or other social programs. If we assume that consumption of product-related waste rises with income, i.e. the price increase burden is progressive, and that the property tax and waste charges are relatively regressive, while the social programs are progressive, then the net result should be a progressive shift in the distribution of income. In addition, if the administrative costs of the product charge are minor, then adjustments in consumption would probably lead to a net welfare gain, resulting from the improvement in allocative efficiency.

Levels of Recycling

The product charge will increase the demand for product-related waste, because of the lack of charges for reused materials. The incremental user charge can be expected to increase the supply of such wastes provided by households, by giving them an incentive to dispose of their wastes by methods other than collection. If the product charge is on the order of 1/2 cent/pound, then the price increase should initially be on the order of $10/ton. This will have little effect on recycling of metals such as aluminum, but should affect other materials, such as glass, steel cans, or newspapers. The price support may also lead to use of these materials as base-load sources, rather than marginal ones, and smooth out the price variations described in the literature.

On the other side of the system, recycling cans, bottles, and newspapers will result in greatly reduced wasteloads, and reduced solid waste collection costs. The easy availability of mechanisms for recycling, such as separate collection, will reduce the chance of diversion to other less desirable modes of disposal, such as littering, and lead to benefits from the incremental user charge scheme. Therefore, the product charge will aid in the diversion of waste from collection to recycling. The imposition of incremental user charges should reinforce this effect, particularly in areas where recycling is available. Reductions in waste collection costs, and increased availability of revenues for municipal recycling programs, may also result.

If the incremental user charge is set at $.50/bag, or about $30/ton, then the total incentive for recycling will be $40/ton for the household if both systems are implemented. However, unless the recycling firms can charge households for the materials collected, they will see a price increase of $10/ton, and, probably, an overabundance of materials available for recycling. The interaction of the two systems will mean that sufficient supply will be available, with demand likely to remain the constraint. A related effect is that, without the product charge, it will be difficult to recycle all the materials removed from the collection/disposal stream. This is a major problem with the incremental user charge system, implemented without the product charge.

Effects on Production Firms

The incremental user charge is not expected to affect these firms, except slightly through the purchase of disposable containers. Therefore, there is no major interaction here.

Effects on Solid Waste Agencies and Firms

This is the area where most of our research has been directed. At present, we believe that most systems operate fairly inefficiently, and that the elasticity of cost with respect to waste generation would be:

- 0.2 for inefficient firms;
- 0.5 to 0.8 for efficient firms;
- 0.7 to 0.9 for firms unconstrained by the real world;

The latter are a special case, similar to the frictionless plane of physics: firms and agencies are not constrained by actual vehicle sizes, the slack related to the need for fixed routes, or the variation in load from week to week; instead, they can operate efficiently under any condition, and therefore can make the best possible adjustments to reductions in the level of waste to be collected. The "efficient" firms go as far in this direction as is practicable, while the inefficient firms make no major adjustments in the face of changes in wasteload, except reductions in overtime and equipment wear.

For major reductions in wasteload, as might occur with introduction of incremental user charges, an elasticity of 0.5 would appear to us to be reasonable. Changes such as this are usually simultaneous with other major system revisions, hopefully in the direction of efficiency. Therefore, the result should be an initial capturing of the potential savings in many cases. If the wasteload reductions are large, for example 40%, then the cost savings will be on the order of 20%. System revenues, though, would drop 40% if the charge was set to cover the before-introduction average cost, and there would be a net deficit.

In order to eliminate this deficit, an increase in charges of 33% is required, given the elasticity of 0.5.

If the product charge revenues were distributed according to population (or the number of households), then communities reducing their waste loads through incremental user charges would benefit. Not only would their waste management costs drop, but their product charge revenues would remain constant, reducing the necessary local contribution.

Let us consider a simple example, with initial collection costs of $30/ton, and 1 ton generated per household annually. The elasticity is 0.5, and the product charge receipts amount to half the waste disposal costs at $30 per ton. The community decides to use the product charge to defray waste collection and disposal costs, and there are no administrative costs.

Therefore, in the initial case, the product charge provides $15/household annually, and another $15 has to be found to cover the costs of collection. Now introduce an incremental user charge set at marginal cost, which is $15/ton or $.25/bag. Assume that use of metered bags breaks even in this case, and that wasteload drops 40%.

We now have the household generating 0.6 tons, and paying $9 annually for collection and disposal. But the product charge adds $15/household, resulting in a total revenue of $24/household, just equal to the collection cost which is reduced by 20%. The product charge revenues cover the fixed costs, as long as they are disbursed on the basis of population.

The product charge itself will have some effect on collection and disposal costs through changing the character of the wastes, and reducing total quantity. This may be significant in some cases, but appears to us to be small in comparison to the effects expected through incremental user charges.

One major issue for solid waste management systems, however, is the ability to find sufficient funds to operate effectively. Many suggestions have been made that these systems are under-funded; this claim, though, has not been sufficiently documented. Both incremental user charges and product charges have been proposed as potential remedies for these problems.

However, product charge revenues will not necessarily be spent on solid waste management only. Because of the number of firms engaged in solid waste collection and disposal, and because of the fragmentation of the industry, it would be difficult to distribute the revenues to all such entities. Assuming that local governments attempt to maximize welfare through their budgeting procedures, there is no need to do so. Tax relief of any form will have similar effects to tax relief for solid waste. Additional services will, it is hoped, have a net social benefit. Thus, there is no strong need to limit the use of the product charge revenues to waste management, given the administrative problems which may be expected.

User charges are likely to represent an attractive revenue source. It is very possible that local governments will view charge levies as an easy method for increasing their budgets for "under-funded" services, leading to gold-plated operations, particularly since they are often monopolies. The imposition of incremental user charges may accentuate the problem of inefficiency by making the system appear equitable to observers and by reducing waste volumes. Such charges, then, may have more chance of adverse taxation effects than flat-rate charges, though this is speculative.

Other Modes of Disposal

The product charges are unlikely to have an effect on the use of littering, garbage grinders, or other modes of disposal; therefore, there is no interaction of concern.

RESULTS AND CONCLUSIONS

Figure 2 shows the relative effects of product charges and incremental user charges based on the above discussion. In general, most of the interactions are beneficial, and the two systems would appear to be able to operate together effectively. The major interactions, in system financing, consumption, and recycling, all appear to be positive, based on certain design assumptions.

However, these design assumptions are fairly critical and should be restated. We have assumed an elasticity of cost with waste generation of 0.5 throughout, which is effectively an assumption about system efficiency. We have assumed that the product charge revenues are disbursed on the basis of population, and that local governments use them to maximize social welfare, either for tax relief or for the provision of services, which may include solid waste management. We have assumed that waste disposal charges have no effect on consumption behavior, or at least that such effects are minimal, and we have assumed that recycling centers will not charge for the waste they receive.

In addition, we have assumed that the incremental user charge will use the marginal cost of collection as the marginal price, with a flat rate for service or another revenue source used for the first block on the rate. This would apparently result in an overly large amount of recycling. Given assumptions such as these, however, it should be possible to design a combination of the incremental user charge and the product charge which does not double-count any costs, and does provide a more complete set of incentives than either form individually.

Effect on	Product charge	Incremental user charge	Combination
Consumption	Shift towards less waste	Minimal	Like product charge
Income	Small effect, probably net increase	Small effect, probably net increase	Small effect, probably net increase
Recycling	Increased demand for base load of recycled product waste	Incentive for households to supply recycled products	Increased recycling with a probable imbalance towards excess supply
Production firms	Shift towards reduced waste in packaging and increased use of recycled materials	No effect	Like Product Charge
Waste management firms	Slightly reduced costs	Reduced costs Increased availability of revenues	Reduced costs Increased availability of revenues
Other modes of disposal	None	Incentive for increased use	Incentive for increased use

Figure 2. Relative effects of user and product charges.

FUNDAMENTAL COMPARISONS OF ALTERNATIVE SOLID WASTE MANAGEMENT POLICIES

by

ALLEN K. MIEDEMA

ACKNOWLEDGEMENTS

The motivation for this paper was the absence of a fairly rigorous case for the conceptual superiority of the product charge. The need arose because our empirical analyses of the product charge and recycling subsidies could not be easily and intuitively related to a paradigm structure that could disentangle otherwise puzzling quantitative results. The crude outlines of the analysis in this paper were suggested by Fred L. Smith, Jr. in a briefing session on a related project during May 1977. Other thoughts in this paper, especially the consideration of practical complications, are indebted to my discussions with both Tayler H. Bingham and Curtis A. Youngblood at RTI.

INTRODUCTION

The "solid waste problem" has received considerable attention for many years and particularly during the last decade. It has been argued that, like air and water pollution, solid wastes "need" to be "controlled." Yet the reasoned case for the control of effluents to common property air and water resources hardly extends in any direct manner to solid waste flows.

The consumption and production residuals that are disposed to the air and water inflict costs on society in the form of health deterioration or, at the very least, an unsightly, uncomfortable, or unenjoyable physical environment. Given the institutions that have emerged in our society, the residuals, aside from litter, that are disposed to the land as solid waste inflict only a financial cost, a cost that is borne ultimately by all individuals who directly or indirectly pay those costs. In the U.S. a large number of state and local ordinances and the efforts of the U.S. Public Health Service have virtually eliminated the egregious damages to human health and physical environments caused by "unabated" solid wastes. (This is certainly not true in less developed countries where fetid open dumps and sewers constantly threaten the lives and well-being of their citizens.) The "abatement" of solid waste has, by and large, taken the form either of government provision of the resources necessary to collect and dispose of all wastes in a sanitary manner or of the imposition of ordinances that require the self-provision of those services by private agents. Where then is the externality?

Superficially it might appear that the current methods of handling solid waste in the U.S. could be cited as an exemplary method for curing the air and water pollution externalities: simply have the government pay for all the abatement costs or have the government pass ordinances that require those expenditures by private agents. Indeed that has apparently been considered a sterling example. With rare exception the chosen "cures" for air and water pollution have been both regulations and government subsidies. The latter include a full complement of government assisted abatement schemes like pollution equipment loan guarantees, extension of preferential municipal bond rates to abating industries, rapid abatement cost write-offs, federal development of abatement technology, government supported technical assistance for abatement methods, etc. The main point is that, regardless of the institutional mechanisms used, the achievement of the "same level" of air and water pollution abatement as is already realized for solid waste might well be viewed by many individuals as considerable, if not fully adequate, progress in the battle against all three externalities.

Thus if the analyst assumes that current solid waste "control" is provided efficiently, it is not surprising that he would defend the materials-, packaging-, and disposable goods-intensive society. He can argue, e.g., Johnson (1960), Becker (1965), and Arthur D. Little, Inc. (1966), that materialism in the form of relatively high consumption of waste intensive goods in both industrial and household production functions enhances social welfare because it conserves other apparently scarcer resources like labor time and energy.

What solid waste imposed externality do we cite in rebutting this argument? The critical first step in the debate is to recognize that "the externality" in solid waste flows is not unlike "the externality" that would still prevail if all air pollution were "controlled" through the use of regulations. Again aside from littering, an externality from solid waste no longer exists in the sense that individual A is directly physically harmed or interfered with by individual B's production or consumption activity. Rather most of the externality in current solid waste management practices is attributable to the maze of market distortions imposed by inefficient, regulation-like pricing, institutional, and legal structures that combine to produce solid waste "control."

A number of those inefficient structures have been enumerated in other sources; e.g., Anderson (1977), Page (1976), and Fiekowsky (1976). Each is mentioned here again for completeness:

Virgin Materials-Biased Tax-Policies

Current tax laws provide for virgin material depletion allowances, capital gains tax advantages on standing timber, and favorable treatment of expenses for exploration and development. All these policies allegedly reduce the relative price of virgin materials and hence cause both the underutilization of recyclables and the underpricing of waste intensive goods.

Virgin Materials-Biased Regulations

A number of administrative policies also distort relative prices of virgin and recycled materials. First, many regulated freight rates are systematically lower for virgin than for recyclable materials. Second, an archaic federal law grants free mineral rights to those who make discoveries on open federal land. Third, under the pretext of quality-assurance, governments enforce virgin materials-biased labelling and procurement requirements.

Free Rider Problem

The predominant method of payment for post-consumer solid waste collection and disposal costs is flat assessments; i.e., the "all-you-can-eat-for-$X-buffet" pricing scheme. The most common method of administering flat assessments is through the application of property taxes, local income taxes, or, given their fungibility, federal revenue sharing funds in payment for municipally provided services. The second most prevalent method is the direct administration of flat assessments by waste collection and disposal contractors. It is argued (Wertz, 1976, p. 269) that this financing method fails to make individuals aware of the waste collection and disposal component of the marginal social costs of the goods they purchase -- like eating another slice of apple pie at the "all-you-can-eat-buffet," discarding another unit of waste costs the individual nothing on the margin. Thus, only the fairly weak, negative income effect from increased flat assessmnt rates, will reduce the purchase of waste intensive goods. Society forfeits the potentially more powerful stimulus for waste reduction in the form of the substitution effect that might be achieved by full marginal cost goods prices that include waste handling costs. This is the classic free rider problem.

Indirect Subsidization of Virgin Materials

Another less commonly mentioned distortion (Summers, 1973, Chap. 3; Smith, 1974, p. 3; Train, 1976, p.1) is attributed to the market's failure to incorporate the eventual collection and disposal costs of some virgin materials in their prices. By comparison, the use of recyclables avoids disposal costs while collection costs are included in their market prices. Therefore, even apart from the distortions in the relative price of virgin and recyclable materials mentioned in 1 and 2 above, this indirect subsidy alone is allegedly accountable for underpriced virgin materials; supposedly this simultaneously induces both excessive use of underpriced materials, and hence excessive generation of wastes, and uneconomically inhibits the use of recyclables.

Besides these four core arguments for the existence of "an externality" in materials markets two other arguments have been propounded. The first is that solid waste flows do entail a genuine externality in the form of littering through which individual A's production and consumption activity adversely affects individual B.[1] The second is that, compared to recyling, virgin material extraction and processing causes a significant amount of other externalities such as air and water pollution and spoilage of scenic natural environments. However, as Anderson (1977, p. 355) points out, the potency of this argument is diminished by the partial removal of these externalities through the implementation of the National Environmental Policy Act, the Federal Water Pollution Control Act, and the Clean Air Act.

A number of federal policies have been advocated or are under consideration to correct these market distortions; e.g., see especially Sec. 8002 (j) of U.S. Congress (1976). Three major generic alternatives have been suggested: (1) product disposal charges, (2) recycling subsidies, and (3) user fees. Product charges would provide for a tax on virgin materials that are eventually to be disposed as post consumer solid waste; the tax would equal the marginal social cost of solid waste handling. Recycling subsidies would provide for direct payments to users of recycled materials on a unit basis. User fees would be direct, volume sensitive charges for waste handling services in proportion to the extent that households and businesses use them.

To date little analytical rigor has been applied to define clearly the comparative strengths and weaknesses of each of these policies.

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[1] Since it may cost as much as 19 times more to collect a littered container than to collect that container from a curbside (Goddard, 1975, p. 39), it is sometimes argued that a corrective "litter tax" is warranted. Although this argument initially seems appropriate and although a significant amount of littering still does occur, the magnitude of the "litter tax" that appears to follow logically from this argument is infinitesimal. The logic would be to set the litter tax equal to the cost of collecting a unit of litter times the proportion of all units that are actually littered. Under such a scheme the proceeds from the litter tax would just cover litter collection costs. For example, an official of the National Soft Drink Association, obviously a vested interest group in view of recent legislative activities on behalf of mandatory deposits, recently proposed a litter tax of .1 cent per beverage container (see "NSDA's Reed Proposes Litter Law; Bottlers Would be Taxed for Program Litter Control Funding," Beverage Industry, 1977). The flaw in this logic derives from waste disposal patterns that result from flat assessment methods for funding solid waste handling services (mentioned above in the discussion of the free rider problem). Since the marginal cost of disposal under this payment method is zero, it undoubtedly accounts for the sanitary processing of what would be a significant volume of litter if point-of-disposal charges were levied. Therefore the collective decisionmaking that leads to "free" waste handling services also undoubtedly accounts for litter volumes far below those that would be observed if those services were prices at their full marginal social costs.

Generally, comparisons of alternative solid waste management policies; e.g., Conn (1975), consist of fairly casual inferences about the general directional effect each policy would have on the waste stream. Evidently previous work fails to distill the essential elements of "the externality" from solid waste flows into a simple model that both precisely defines the market distortions that characterize materials markets and provides a rigorous theoretical basis for inferences about the conceptual superiority of one solid waste management policy over another.

The purpose of this paper is to examine the real income and market effects of each of the three major alternative solid waste management policies and of the status quo and to determine whether these policies can be ranked in terms of their ability to increase social welfare.

The analysis begins with the development of a paradigm model of a simple economy in the next section. The model assumes the existence of only the free rider problem and the indirect subsidization of virgin materials; i.e., not only all three alleged sources of downward biases in relative virgin materials prices, but also the littering problem are assumed to be nonexistent. Also, zero transactions costs are assumed. In a later section this paradigm is used to analyze each of the four policy settings. The policy simulations presented there are used to draw tentative conclusions about the relative real income, net waste, waste generation, resource recovery and recycling rate effects of the alternative policies.

THE MODEL

Since the objective of this analysis is to make statements about the welfare characteristics of alternative solid waste management policies, it is necessary to define a very rudimentary general equilibrium model of a paradigm economy. The model development parallels that of neoclassical price theory, with appropriate departures to account for the materials flows that cause the solid waste problem.

The macroeconomic setting is assumed to be identical to that of the standard (timeless) general equilibrium model, except that a constitution and government are assumed. The government represents all individuals through its constitutional authority to protect resource ownership and to expropriate (tax) and expend those resources. As usual the economy is assumed to be autarkic and both exchange and (in this model) government functions are undertaken costlessly.

All production activities occur within profit maximizing competitive firms that are fully owned by individuals. The firms themselves are not endowed with resources and do not consume. Rather all resources are owned and provided by individuals who are paid the value of the output (including rents) attributable to the resources they provide. Thus the macro accounting identity is met: the total value of output (GNP) is identical to total national income.

A major departure of this model from the standard neoclassical model is that all resources other than a single natural resource are subsumed into a single factor of production. This resource endowment is a composite of human and physical capital from which a fixed total, k units, of services are available. The resource endowment is owned in aliquot shares by the individuals and is completely (and costlessly) mobile among all production activities in the economy. The society is also endowed with a "mine" from which the natural resource, "clay," is extracted. Once extracted, this material flows through the economy and can either be recycled or disposed to a sanitary landfill.

On the demand side all individuals have identical but independent preference functions. Therefore, envy and benevolence are absent and a single indifference curve can be used to represent society's real income. Also all resource expropriation (taxation) by the government, whether by excise taxation or direct property (income) taxation, is borne in aliquot shares by the individuals in the economy. Similarly, the benefits of government expenditures are enjoyed equally because individuals' preference functions and resource endowments are identical.

With this general setting it is now possible to define more fully the specific characteristics of production and consumption activities within the paradigm economy. Only two final goods are produced: a "beverage" and a residual (numeraire) good. The beverage is packaged in a "clay" container which, when disposed, constitutes the only solid waste generated within the economy. A single unit of "contents," f, is assumed to be required along with a single container in producing a unit of beverage. This fixed coefficients beverage production activity simply represents an operation that (costlessly) blends the beverage contents and containers; i.e.,

$$q = \min(j,f) \tag{1}$$

where q = beverage output,
j = containers, and
f = contents.

Because of the specialized form of (1), $q = j = f$.

The two intermediate goods used in (1), containers and contents, are produced by applying the capital output. The production process for contents is assumed to be a simple constant-returns process,

$$f = \rho k \tag{2}$$

where ρ = parameter of the beverage contents production process.

A "used" container is -- like modern non-refillable beverage containers -- unsuitable for reuse; it must either be disposed or recycled into a new container production process. The latter is described by a simple Cobb-Douglas production function,

$$r = \alpha_0 k^{\alpha_1} \tag{3}$$

where r = number of containers produced from recycled containers, and

α_0, α_1 = parameters of the recycling and container reconstitution process.

The activities represented by the production process of (3) include the collection, transfer, and reconstitution of "used" containers into new containers.

Alternatively a new container can be produced from virgin "clay" extracted from the "mine." The entire process of mining, materials processing, and container manufacturing from virgin material is also described as a simple Cobb-Douglas production process.

$$v = \beta_0 k^{\beta_1} \tag{4}$$

where v = number of containers produced from virgin material, and

β_0, β_1 = parameters of the mining and container manufacturing process.

The total number of new containers (and of beverage units produced) is identically the sum of those produced from recycled containers and those produced from virgin materials; i.e.,

$$q = j = v + r. \tag{5}$$

The quality and appearance of containers produced from recycled material is assumed identical to those produced from virgin materials.

Both the basic production processes of (3) and (4) and the (costless) blending operations of (1) and (5) are assumed to be completely free of materials losses. Also it is assumed that none of the used containers are lost. Thus the total flow, h, of potential solid waste is exactly equal to the number, j, of containers used or, equivalently, the number of units, q, of beverages consumed.

The numeraire good, which represents all other goods besides beverages, is also assumed to be produced by a simple constant returns production operation,

$$x = \pi k \tag{6}$$

where x = numeraire good, and

π = parameter of the numeraire good production process.

The utility function shared by all individuals is a simple exponential function

$$u = q^{\lambda} x^{1-\lambda} \tag{7}$$

where u = utils enjoyed by each individual, and

λ = parameter of the utility function.

It is also assumed that if even a single container is littered; i.e., neither recycled nor disposed, all individuals' utility becomes negative.[2] Therefore, all individuals will unanimously vote to have the government collect and dispose all used containers if the government is as efficient as individuals in completing that activity. Finally individuals' utility is assumed to be completely unaffected by whether a used container is disposed as solid waste or recycled; i.e., utility is independent of the recycling rate.

If prices in the paradigm economy are denominated in units of capital services, and if disposable incomes are regarded by individuals as completely exogenous, then individual utility maximization requires that for the society as a whole the following expression is maximized

$$\Omega = q^{\lambda} x^{1-\lambda} + \Delta(E - p^{*}q - \pi x) \tag{8}$$

where E = society's aggregate disposable income,

p^{*} = price of beverages including excise taxes, if any, and

Δ = Lagrangian operator.

Since E is actually the sum of individuals' disposable incomes and since the latter are assumed to be perceived as exogenously given, the partial differentials of E with respect to q and x are zero irrespective of the solid waste management policy that is applied. This is assumed even though E may be substantially affected at the macro level by choices of q and x, since individuals always require their government to tax them for the cost of collecting and disposing the used containers that are not recycled.

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[2] If L is the number of units littered, a more precise definition of the utility function of (7) might be $u = (1-\ell L)q^{\lambda}c^{1-\lambda}$ where $\ell > 1$.

Under these assumptions the solutions to the first order conditions yield the aggregate demand functions for q and x in terms of aggregate disposable income, the price of beverages, and the parameter of the utility function. Specificaly, the aggregate demand functions are

$$q = \lambda E/p^* \text{ and } \tag{9}$$

$$x = (1-\lambda)E/\pi$$

The production process for the collection and disposal activity is also assumed to be a constant returns process and is assumed to be identical whether the service is provided by the government or by individuals,

$$d = \mu k \tag{10}$$

where d = number of used containers collected and disposed to a sanitary landfill, and

μ = parameter of the collection and disposal process.

Figure 1 summarizes resource and product flows in the paradigm economy. Only beverages and the numeraire good are consumed directly as final products. All other products in the economy are intermediate goods used in or associated with the waste intensive good. Three of the five basic industries in the economy, i.e., those industries that directly use the capital input, are intermediate goods production processes for f, r, and v; the other two are the numeraire good production activity, x, and waste collection and disposal, d. Economic forces together with solid waste management policies determine the extent to which wastes are either recycled or disposed to a sanitary landfill, the extent to which virgin materials-based and recycled materials-based containers are substituted in container production, and the extent to which beverages and the numeraire good are substituted in consumption.

ANALYSIS

The paradigm of the previous section can now be used to examine the materials and resource flows as well as the price and real income effects associated with four alternative states of the world implied by four policy settings. The four settings to be analyzed are: (1) non-intervention of the government in either final product or input markets; i.e., the status quo, (2) government payment of a subsidy for recycling, (3) government imposition of a collection and disposal or user fee, or equivalently in this model, of an excise tax on beverages, and (4) government imposition of a product

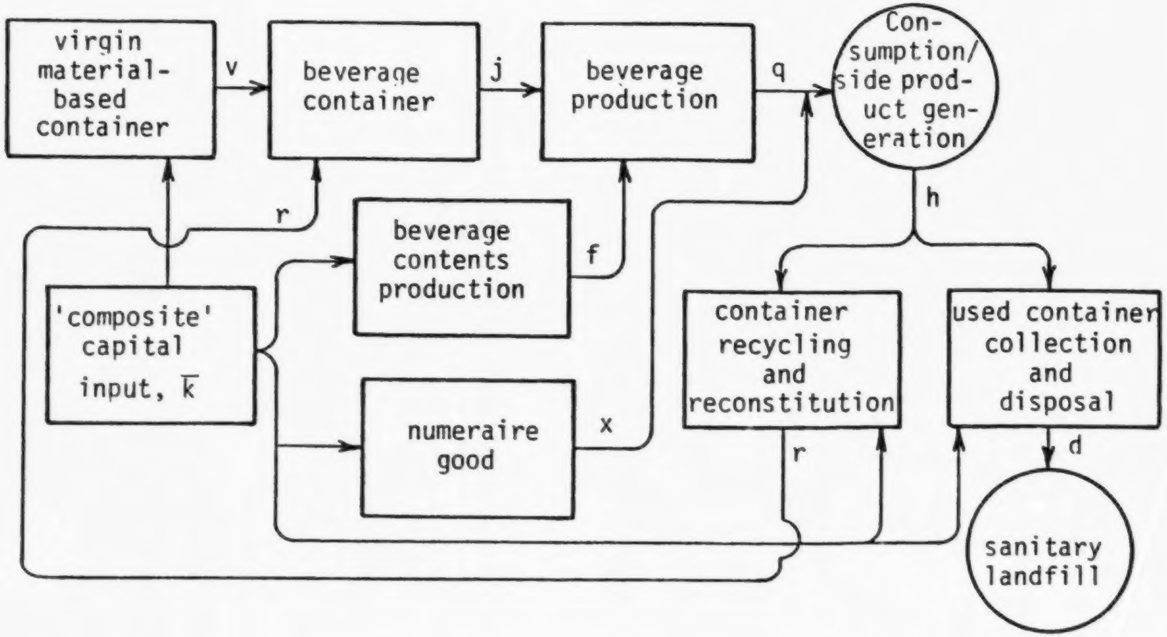
virgin material-based container
v
beverage container
j
beverage production
q
Con-sumption/side prod-uct gen-eration
h
r
beverage contents production
f
'composite' capital input, $\bar{k}$
numeraire good
x
container recycling and reconstitution
r
used container collection and disposal
d
sanitary landfill

Figure 1. Paradigm economy resource and product flows.

disposal charge on the virgin material content of eventual side products. These four policies will be referred to as the status quo, user fee, recycling subsidy and product charge policy options.

The analysis of each policy develops the equations whose solutions characterize market equilibria and real income levels in the paradigm economy under alternative policy choices. Specifically, a total of six equations and six endogenous variables define market equilibria. These variables are: (1) capital services used to produce virgin materials-based containers, k ; (2) capital services used to produce recycled materials-based containers, k ; (3) aggregate consumption of beverages, q; (4) the f.o.b. price of beverages, p; (5) rents from container production, R; and (6) aggregate disposable income level, E. From the six endogenous variables others such as the level of numeraire goods consumption, x, and the real income level, u, can be computed using (9) and (7), respectively. As would be expected, some of the six equations differ depending upon the particular policy choice that is assumed. Therefore, the next section first defines the particular general equilibrium system that obtains under each of the four policy alternatives. Then, since all systems are fully nonlinear, we present some policy simulations for assumed values of the various parameters in each general equilibrium system. The results of these simulations are then used to draw conclusions about the comparative desirability of the four alternative solid waste management policies. Table 1 defines the parameters and unknowns that appear in the alternative six equation systems.

TABLE 1. GENERAL EQUILIBRIUM SYSTEM VARIABLES

Classification	Variables
Function parameters	α, β, γ
System parameters	$w, \bar{k}$
Policy parameters	t, a
System unknowns	k_v, k_r, q, p, R, E

Policy-Specific General Equilibrium Equations Systems

Each of the four policies considered here implies a different method of government intervention to manage solid wastes. Each method in turn may imply a unique profit function for beverage producers. Therefore the profit equation is the first specified below in the general equilibrium systems associated with each policy. Then, using the profit maximization assumption, the second equation expresses the optimum quantity of capital to be used in recycled materials-based container production (determined from the first order conditions) as a function of that to be used in virgin materials-based container production. The third equation, also derived from the first order conditions for profit maximization, expresses the price of beverages as a function of the optimum quantity of capital services in recycled materials-based container production. The fourth equation defines disposable national income; i.e., national income net of government expenditures for waste handling services. The fifth equation simply specializes the aggregate demand function of (9) for each policy option. Finally the identity of (5) completely identifies the system for each policy.

To simplify the algebra the production functions of (2), (3), (4), and (6) are further specialized by assuming that $\rho = \alpha_0 = \beta_0 = \pi = 1$ and by suppressing the subscript on α_1 and β_1. While they are notationally convenient, these assumptions do not substantively affect the conclusions that derive from the policy simulations of the next section.

Status Quo--

The status quo policy is intended to reflect the basics of current waste handling practices. Specifically, government (or a group of competitive private firms) is assumed to provide waste collection and disposal services under a flat assessment payment scheme. The property tax, for example, is one method by which this is accomplished in practice. A similar pricing technique used by private waste collection and disposal firms is to charge a flat rate per period for waste removal services regardless of the volume generated.

Under the status quo beverage industry profits, R, will simply be the difference between beverage sales and total input costs. Since one unit of contents costing one unit of capital services ($\rho = 1$) is required per unit of beverage output, the cost of contents will be q. The cost of containers will just be the sum of all units of capital services used in container production. Thus industry profits are

$$R = (p-1)q - k_r - k_v$$

where R = beverage industry profits.

When the specialized forms of the container production functions, (3) and (4), are substituted into (5) and when the latter replaces q in the above expression, beverage industry profits can be re-expressed as

$$R = (p-1)(k_r^{\alpha} + k_v^{\beta}) - k_r - k_v. \qquad (11)$$

When (11) is differentiated with respect to k and k and the resulting expressions are set equal to zero, these two first order conditions can be solved to express the profit maximizing quantity of k as a function of the production function parameters and k ,; i.e.,

$$k = [\beta/(\alpha k_v^{1-\beta})]^{1/(\alpha-1)}. \qquad (12)$$

The first order condition in which the expression of (11) is differentiated with respect to k_r can also be solved to express the f.o.b. price of beverages as a function of k_r,

$$p = (k_r^{1-\alpha}/\alpha) + 1. \qquad (13)$$

Disposable national income under the status quo is the value of its fixed endowment of capital services, $\bar{k}$, plus profits from beverage production, R, less income taxes required to pay for waste handling; i.e., less the product of the unit cost of waste handling, w, and the flow of virgin materials used (and discarded) or

$$E = \bar{k} + R - wk_v^{\beta} \qquad (14)$$

Finally since no excise taxes are imposed under the status quo, the f.o.b. price is the retail price, p = p*, and the aggregate demand function of (9) becomes

$$q = \lambda E/p. \qquad (15)$$

Table 2 summarizes the six equations of the general equilibrium system that is defined by a status quo solid waste management policy. This system can be solved for k_v, k_r, q, p, R, and E, although not in closed form.

TABLE 2. GENERAL EQUILIBRIUM EQUATIONS SYSTEMS

Policy choice	Equation System					
Status quo	(11),	(12),	(13),	(14),	(15),	(5)
Recycling subsidy	(16),	(17),	(18),	(19),	(15),	(5)
User fee	(11),	(12),	(13),	(20),	(21),	(5)
Product charge	(22),	(23),	(13),	(24),	(15),	(5)

Recycling Subsidies--

Among the proposed legislative remedies for the solid waste problem a recycling subsidy policy is one of the most frequently mentioned. Anderson (1977) reviews in some detail two major federal bills, H.R. 148 and H.R. 10612, that would grant alternative forms of recycling subsidies. Those documents and others referenced by the National Commission on Supplies and Shortages (1976, pp. 155-72) provide details on the nuances of specific subsidy plans.

For this analysis the simplest possible form of a recycling subsidy is assumed. Specifically it is assumed that a flat subsidy rate, a, is paid directly to beverage producers for each recycled container they use. Therefore the beverage industry profit function under a recycling subsidy differs from that under the status quo policy in that profits are augmented by subsidy payments; i.e,

$$R = (p-1)(k_r^{\alpha} + k_v^{\beta}) - k_r - k_v + a\, k_r^{\alpha}. \qquad (16)$$

Differentiating (16) and solving the first order conditions yields an alternative expression for the optimum usage of capital services in recycled materials-based container production,

$$k_r = [\beta/(\alpha(k_v^{1-\beta} + \beta a))]^{1/(\alpha-1)}. \qquad (17)$$

Also, one of the first order conditions for a maximum of (16) can be solved to develop a price equation analogous to (13),

$$p = (k_r^{1-\alpha}/\alpha) - a + 1. \tag{18}$$

Disposable national income under the recycling policy differs from that under the status quo in that incomes must be further taxed to pay the recycling subsidies. Therefore, disposable income will be

$$E = \bar{k} + R - wk_v^{\beta} - ak_r^{\alpha}. \tag{19}$$

Of course the absence of an excise tax on beverages implies that the aggregate demand function under a recycling subsidy is the same as under the status quo; i.e., equation (15). The six equation general equilibrium system under the recycling subsidy is also summarized in Table 3.

User Fee--

The user fee policy in the paradigm economy represents either of two situations. First, the policy can represent the imposition of a volume-sensitive waste tax at the point of disposal. For example, a tax equal to the cost of used container collection and disposal could be levied on each container that is thrown away. Alternatively, given the assumption that transactions costs are zero, the policy is identical, in the paradigm economy, to a litter tax, since government can costlessly impose a charge either at the point of disposal (user fee) or point of purchase (litter tax).

Under a user fee policy the profit function and the associated solutions for k_r and p from the first order conditions are identical to those under the status quo — equations (11), (12), and (13) — because the policy does not directly affect beverage producers.

However, when a user fee is applied at the rate of t per unit of beverages consumed (and per unit of container discarded by consumers), disposable national income is increased over that under the status quo by the amount of the user fee proceeds. Therefore disposable national income will be

$$E = \bar{k} + R + tq - wk_v^{\beta} \tag{20}$$

Of course, the specification of the aggregate beverage demand function will also be affected since the effective price that consumers face will be the sum of the f.o.b. price of beverages and the user fee; i.e., $p^* = p + t$ so

$$q = \lambda E/(p+t). \tag{21}$$

The general equilibrium equation system under the user fee policy will, therefore, consist of equations (11), (12), (13), (20), (21), and (5).

Product Charge--

A product charge policy would, as usually conceived (see Smith, 1974; Page, 1976; and U.S. Senate, 1976), impose a unit tax on all virgin materials that are eventually disposed. In the paradigm economy this implies that every virgin materials-based container will be taxed at, say, the rate t. Therefore, beverage producer profits will be reduced by the amount of these taxes so the modified profit function is

$$R = (p-1)(K_r^{\alpha} + k_v^{\beta}) - K_r - K_v - t\ k_v^{\beta}. \tag{22}$$

The corresponding solution of the first order conditions for k is

$$k_r = [\beta/(\alpha(k_v^{1-\beta} + t\beta))]^{1(\alpha-1)} \quad . \tag{23}$$

The solution for p is identical to that under the status quo and user fee policies; i.e., to (13).

Aggregate disposable income will be increased over that under the status quo by the amount of the product charge proceeds so

$$E = \bar{k} + R - (w-t)k_v^{\beta}. \tag{24}$$

Finally the specification of the aggregate demand function for beverages will be the same under the product charge policy as under the status quo and recycling subsidies. The resulting six equation system is summarized in Table 2.

Solid Waste Management Policy Simulations

Since closed-form solutions of the four alternative general equilibrium systems are not attainable, fixed values were chosen for the parameters identified in Table 2 and the resulting nonlinear systems were then solved numerically using the simple half interval method (Southworth and Deleeuw, 1966). For all policy simulations the following parameters are held constant at the indicated values: $\lambda = .2$, $w = 10$, $\bar{k} = 10{,}400$. Then in three different sets of simulations the production function parameters α and β were varied to analyze the effects of differences in the degree of diminishing returns (diseconomies of scale) in the virgin materials-based as opposed to the recycled materials-based container manufacturing industries. The assumed alternative parameter values are given in Table 3 and, as indicated, correspond to three possible situations: (I) both the virgin and recycled materials-based container manufacturing industries have equal diseconomies of scale, (II) the recycled materials-based industry has greater diseconomies, and (III) the virgin materials-based industry has greater diseconomies. Diseconomies of scale obviously imply that increasing amounts of inputs must be used to produce additional containers. In the recycling materials-based industry this could be caused by diminishing quality of recyclable materials or by increasing unit collection costs as the recycling rate increases. In the virgin materials-based industry it could be caused by diminishing ore quality and capital fixities in mining industries.

TABLE 3. CONTAINER PRODUCTION FUNCTION PARAMETERS FOR THREE ALTERNATIVE SETS OF POLICY SIMULATIONS

Policy simulation	Production function parameter values		Container manufacturing industry with greater diseconomies of scale
	α	β	
I	.5	.5	Neither
II	.4	.6	Recycled materials-based
III	.6	.4	Virgin materials-based

For each of the three sets of policy simulations the single solution for the status quo was obtained. Since the status quo is always a special case of all three alternative policies -- i.e., all four equation systems of Table 3 are identical when $t = a = 0$ -- that solution is also a solution for the zero value of the policy parameter associated with each. Then the policy parameter was incremented by a value of 2 up to a value of 20 (twice the marginal cost of collection and disposal). The resulting solution values of interest are displayed in the three panels (labeled I, II, and III to correspond with policy simulations I, II, and III) of Figures 1-4. The figures display, respectively, the real income, net waste, waste generation and resource recovery, and recycling rate effects of the alternative policies. Each of those effects is discussed in turn in the following four sections which compare the four alternative policies.

Real Income Effects--

Figure 2 displays the most important results because it shows the fate of individuals' real income under alternative solid waste management policies. Several critical conclusions are suggested by these results:

The product charge maximizes social welfare when the charge rate is set equal to the marginal cost of waste collection and disposal. No other policy at any setting of their policy parameters can generate as high a level of real income.

Unless the product charge rate is well in excess of the marginal cost of waste handling, w, society will be better off with a product charge set at any level than under the status quo.

At any identical charge, subsidy, or fee rate the product charge is superior to both the user fee and recycling subsidy policies and the user fee is in turn superior to the recycling subsidy.

When the diseconomies of scale are substantially greater in virgin materials-based container manufacturing than in recycled materials-based manufacturing none of the innovative solid waste management policies are markedly superior to the status quo.

Only the product charge is always superior to the status quo when the policy rate is set equal to the marginal cost of waste collection and disposal.

All three innovative policies are superior to the status quo for values of the appropriate policy rate that are close to zero.

Net Waste Effects--

Figure 3 shows the associated net waste that is generated. All three alternative policies lead to a lower net flow of waste that needs to be collected and disposed by the government. At identical charge, subsidy, and fee rates the product charge causes the lowest net waste flows. If diseconomies of scale are greater in the virgin material-based container manufacturing industry user fees are associated with the highest net waste flows. Otherwise recycling subsidies are.

Waste Generation and Resource Recovery Effects--

The reasons for the preceding results are displayed in Figure 4 which shows both the gross waste generation and recycling levels. The upper set of curves in each panel represents beverage consumption (waste generation) levels and the lower set represents recycling levels. The vertical distance between the two curves for each policy are the net waste effects shown in Figure 3. The superiority of the product charge is also suggested by the fact that it causes both a positive waste reduction effect (the upper dotted line has a negative slope) and a positive resource recovery effect (the lower dotted line has a positive slope). These reinforcing effects contrast with the recycling subsidy which causes a perverse (negative) waste reduction effect with a positive resource recovery effect and with the user fee which causes a positive waste reduction effect with a comparatively perverse resource recovery effect.

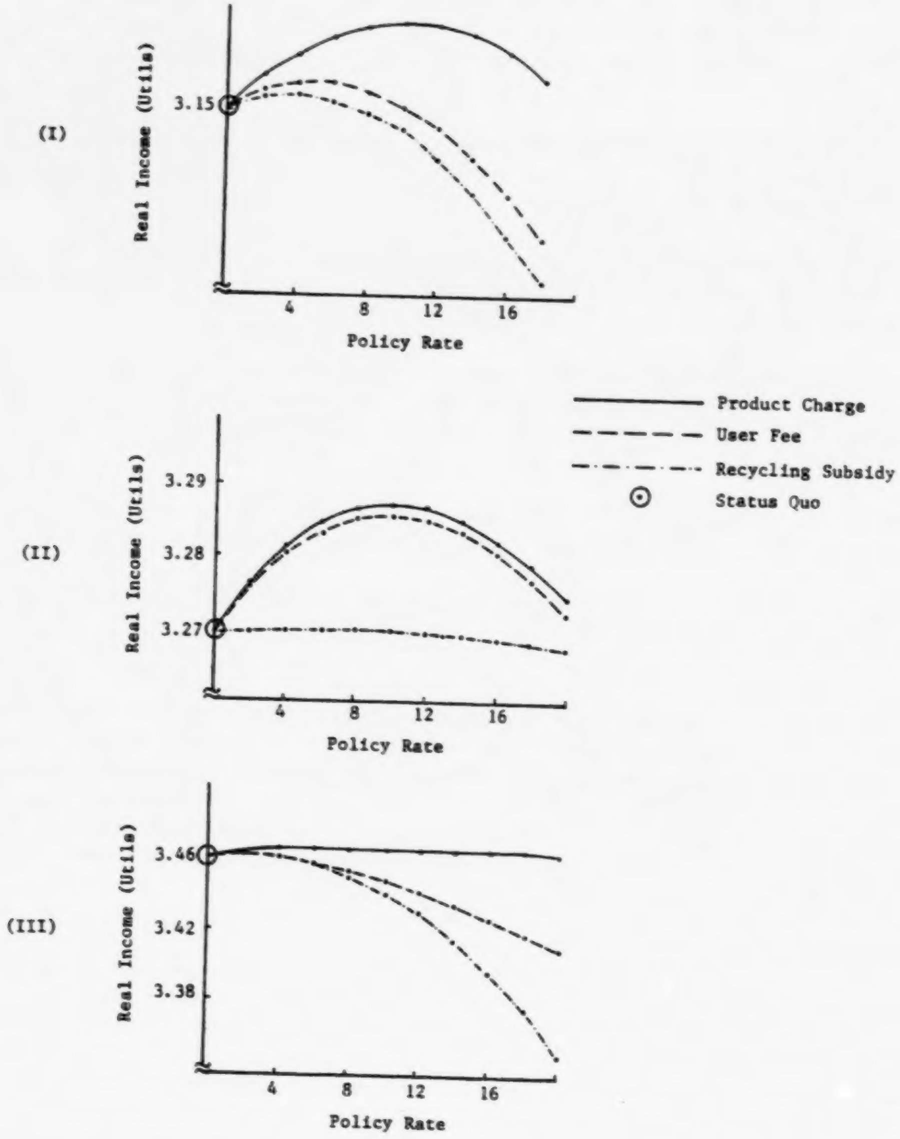

Figure 2. Real income effects.

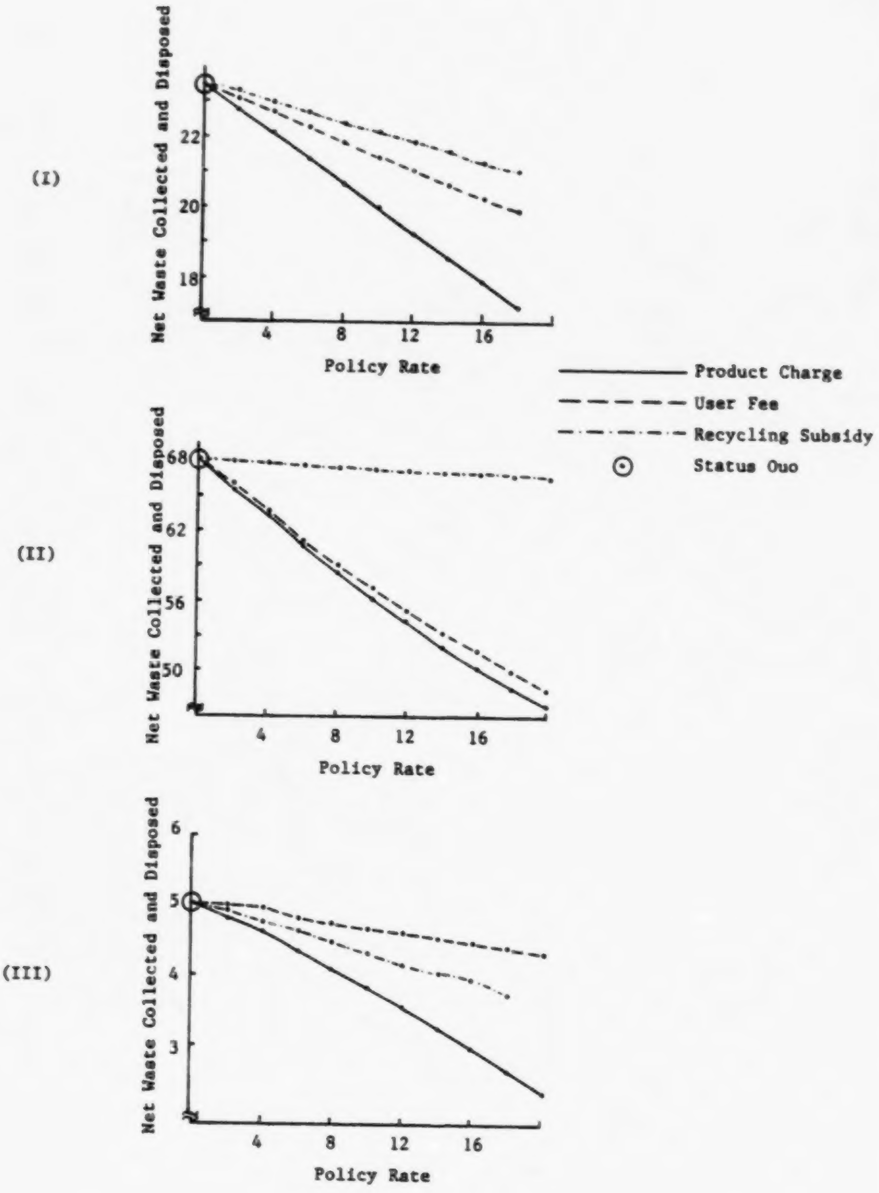

Figure 3. Net waste effects.

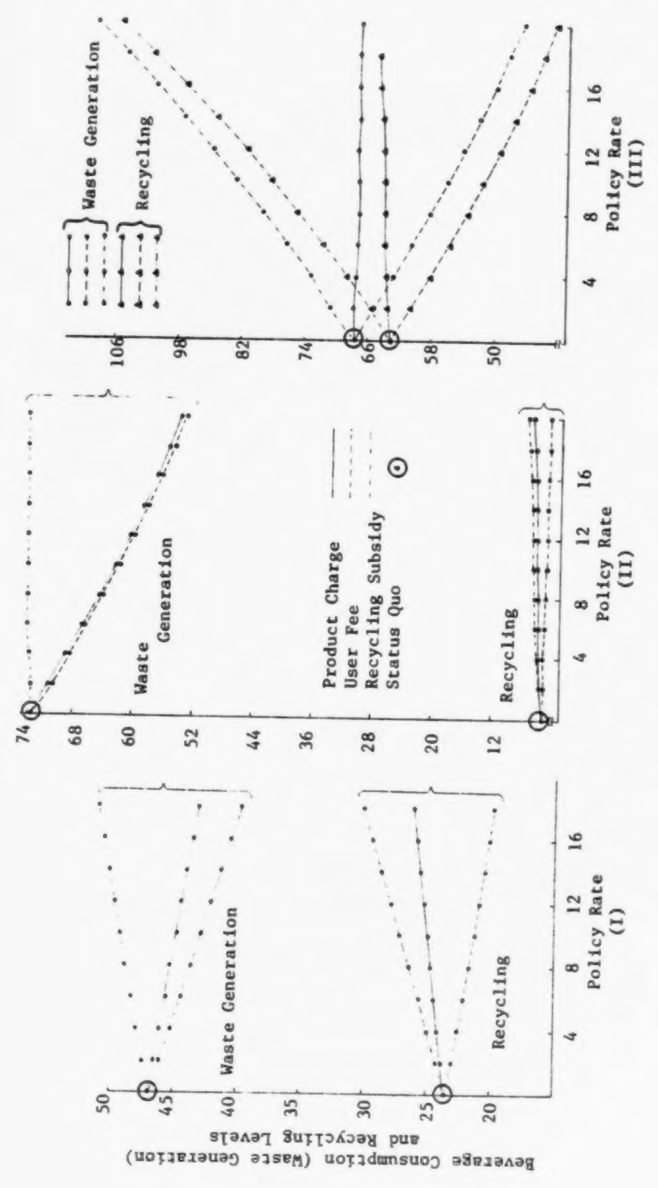

Figure 4. Waste generation and resource recovery effects.

Recycling Rate Effects--

Figure 5 shows the recycling rates (recycling levels divided by gross waste generation levels) associated with each policy. The recycling rates are greater under the product charge at any particular charge/subsidy rate than under the recycling policy, except under policy simulation III when the comparatively greater returns to scale in recycled materials-based container manufacture lead to higher recycling rates under a recycling subsidy. Also, for all positive charge and subsidy rates, the recycling rates under either of those two policies exceeds that associated with the status quo. That is not the case for the user fee under which the recycling rate may actually decline (simulation III).

This figure combined with Figure 2 makes a point that should be, but apparently isn't always, obvious: policy-induced increases in the recycling rate are very poor indicators of associated changes in social welfare. For example, even though the user fee leads to much lower recycling rates than the recycling subsidy (as shown by Figure 4), it is nonetheless uniformly superior to the recycling subsidy in a social welfare sense (as shown by Figure 1). Also, a very high product charge rate would actually make society worse off than under the status quo, but it would at the same time further increase the recycling rate.

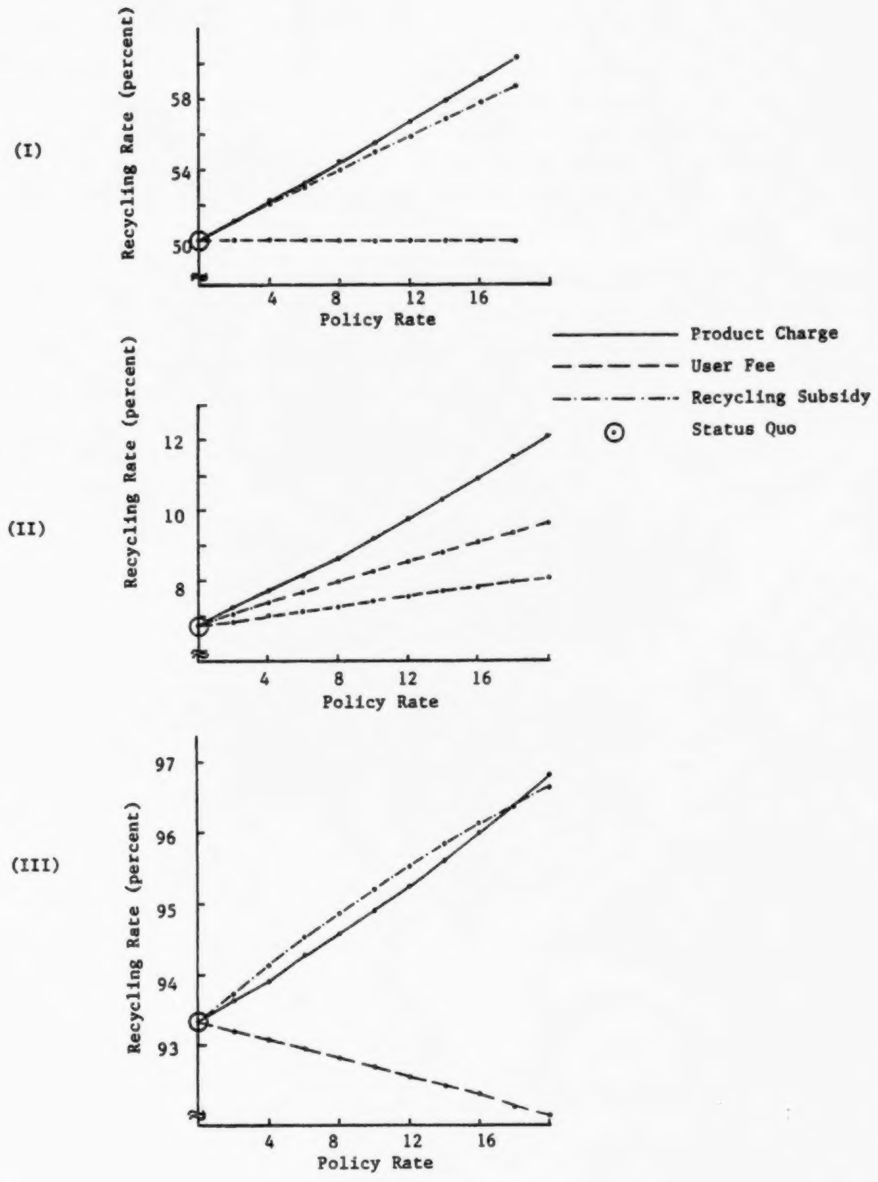

Figure 5. Recycling rate effects.

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SECTION 5

PRICING AND RESOURCE RECOVERY TECHNOLOGY

"Conditionally Predictive Estimates of Secondary Materials Supply" (Tayler H. Bingham, Curtis E. Youngblood, Philip C. Cooley).

"Secondary Material Demand and Supply Responses" (Robert C. Anderson).

CONDITIONALLY PREDICTIVE ESTIMATES OF SECONDARY MATERIALS SUPPLY

by

TAYLER H. BINGHAM
CURTIS E. YOUNGBLOOD
PHILIP C. COOLEY

INTRODUCTION

The effectiveness of a number of solid waste policies, most notably the disposal charge, is influenced by the potential supply of secondary materials. The initial efforts in this area were, necessarily, descriptive studies that presented materials flows, described solid waste management practices and discussed the institutional and economic impediments to additional resource recovery. Quantitative studies of secondary materials supply from the post-consumer (municipal) waste stream have been hampered by a number of obstacles--most notably the lack of an adequate data base, and for many materials, the lack of any significant level of recycling.

There are basically two approaches to supply estimation: econometric and process modeling. The econometric method utilizes statistical techniques and empirical observations to develop positive estimates of behavioral responses to exogenous events. These estimates relate to what has happened in the past and can provide the basis for good predictions if there has been no change in the economic or institutional relationships. The process model approach to supply estimation is normative--it describes what should happen, given various underlying factors and the objective function of the institution. The quality of the predictions developed from the use of a process model is only as good as the set of choices that are modeled and the relevance of the assumed objective function to that of decision makers.

A small number of econometric studies of secondary materials supply have been undertaken. Most of the estimates indicate an inelastic supply function for the secondary mater)als studied. Frequently, however, the materials studied have not been post-consumer wastes but rather obsolete scrap from industrial establishments.

This paper presents the results of utilizing a process model to predict the quantity of secondary materials recovered from the solid waste stream under alternative prices for these materials. The quantity-price data are then used to estimate a conditionally predictive set of own- and cross-price supply elasticities for secondary materials.

The general approach has been employed by Griffin (1977) in another setting where the joint product nature of production was important--petroleum refining. The joint product problem, which arises when the production of one product (e.g., beef) results in the concomitant production of another (e.g., hides) is not handled well by current econometric methods. Many of the existing resource recovery systems have important joint product features. For example, aluminum recovery requires the recovery of ferrous materials.

Material flows are identified in the following section. This is followed by a discussion of the solid waste management options, their costs, and the process model. Finally, statistical estimates of the supply of secondary ferrous, glass and aluminum are presented and some conclusions drawn.

MATERIALS FLOWS

The process model presented later in this paper uses a materials balance framework to account for all materials flows. In this section the materials and their major paths are identified.

In 1976, individuals, commercial establishments, and institutions generated almost 145 million tons of solid waste (about 3.7 pounds per person per day) of which nine million tons, or six percent, were recycled. Thus, approximately 136 million tons were disposed of by dumping, littering, landfilling, and incinerating. Table 1 shows the breakdown of municipal solid wastes used in this study. The category "all other waste" is the residual which is included for completeness. It does not include agricultural and mining wastes, construction and demolition debris, abandoned vehicles, or industrial wastes.

Current levels of recycling are presented in table 1 for each of the five components of the municipal waste stream. Paper and aluminum have the highest recycling rates. The relative availability of aluminum recycling centers and the price paid for aluminum cans ($340 per ton in 1976) make aluminum an attractive material to recover. Newspapers, corrugated containers, and office paper constituted over three-fourths of all paper recycled in 1976. When separated from other wastes at the point of generation (commercial and business establishments), old corrugated containers and sorted white ledger (office paper) have the characteristics cited by Page (1976) that make a material more amenable to recycling: mass, concentration of mass, known contaminants, and homogeneity, or consistency. Newspapers, while generated in sufficient quantities, are dispersed over a much wider area than are corrugated container and office paper. A paper drive accumulates these dispersed quantities into a mass sufficient for recycling.

Glass and ferrous metals from postconsumer wastes are not recovered in large quantities. The raw materials used to make glass are so cheap and abundant that there is little incentive to recover glass from postconsumer

TABLE 1. COMPOSITION AND DISPOSITION OF POSTCONSUMER SOLID WASTES, 1976

	Composition		Disposition		
			Recycled		
	Amount (10^6 tons)	Proportion	Share (%)	Amount (10^6 tons)	Disposed (10^6 tons)
Paper	50.4	.348	16.1	8.1	42.3
Glass	13.9	.096	2.7	.4	13.5
Ferrous	11.2	.077	0.9	.1	11.1
Aluminum	1.2	.008	8.8	.1	1.1
All other waste	68.0	.470	0.0	0.0	68.0
Total (Average)	144.7	1.000	6.0	8.7	136.0

Source: Adapted from estimates by Franklin Associates, Ltd. for the Resource Recovery Division, Office of Solid Waste, U.S. Environmental Protection Agency, January 1978.

wastes. Cullet of known quality needed in the glassmaking process is easily generated by the producer. Cullet from municipal wastes, on the other hand, must be cleaned of contaminants like metal and ceramics and color sorted. Its weight-to-value ratio is so large that transporting it more than a few miles is uneconomical. Ferrous metals, too, suffer from contaminants, chiefly tin, that must be removed prior to reuse in steelmaking. Ferrous scrap is also much less valuable than aluminum.

As shown in figure 1, the generated solid waste may either go directly to the municipal or private collector, or some of the more useful materials may be source separated and recycled. Source separation can be either voluntary or mandatory. The majority of the recycling activity presented in table 1 represents the voluntary action of the waste generators.

Voluntary source separation alters not only the composition of the waste stream but also its energy content. This affects the economics of the various waste management options facing municipalities, as will be seen below. Counterbalancing this effect, however, voluntary source separation decreases the volume of municipal wastes that must be collected and disposed. One difference between mandatory and voluntary source separation is that the revenues from the sale of the secondary materials accrue directly to the municipality under mandatory separation, thus offsetting some or all of the incremental costs of separate collection.

The actual waste collected by the private firm or municipality is usually unseparated. However, in some areas, separation of certain fractions is required as a condition of service--mandatory source separation. The city (or the city's contracted hauler) collects these source-separated wastes for delivery to a processor. In voluntary activities, this service is provided by the private sector.

A survey of resource recovery and waste reduction programs throughout the U.S. (McEwen, 1977) showed that as of August 1974, 174 cities had implemented separate collection programs. Of these, 156 collected newsprint only; the remaining 18 collected various combinations of mixed paper, glass, and cans. Whether all of these programs are mandatory in the sense that we use the word is doubtful.

Unlike some forms of voluntary source separation, there are not direct financial incentives for generators to comply; since enforcement of the municipal ordinance requiring source separation is practically impossible, compliance has a strong voluntary element. If the benefits are to outweigh the costs, it requires the cooperation of waste generators.

Mandatory source separation reduces the volume of waste requiring disposal, just as voluntary recycling does. This is increasingly important as landfill space becomes more scarce. Thus, avoided disposal costs are one of the benefits of mandatory source separation. It also alters the volume, composition, and energy content of the solid waste stream, which naturally affects the economics of processing and disposing of the remaining wastes.

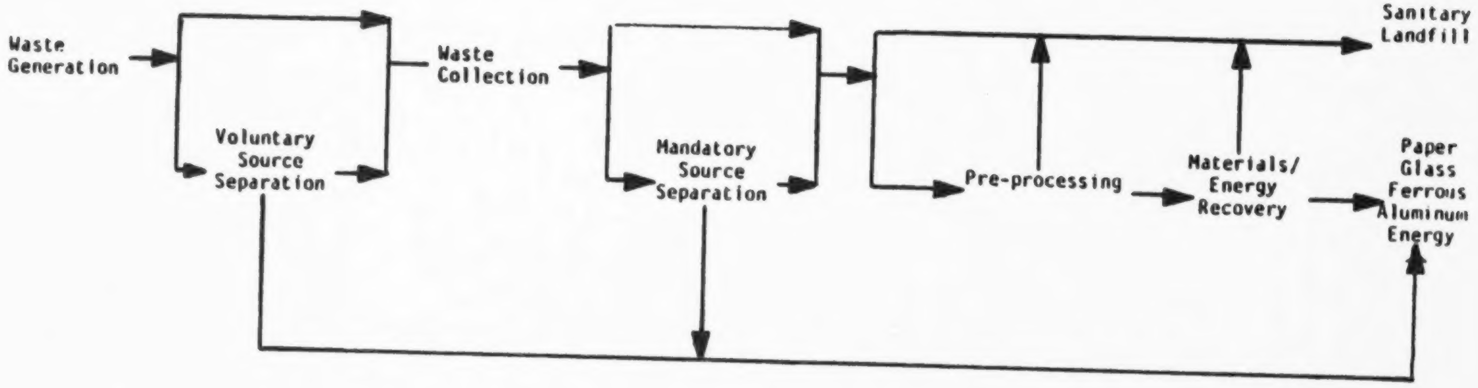
Waste Generation
Voluntary Source Separation
Waste Collection
Mandatory Source Separation
Pre-processing
Materials/ Energy Recovery
Sanitary Landfill
Paper
Glass
Ferrous
Aluminum
Energy

Figure 1. Solid waste material flows.

The unseparated wastes next follow one of three paths leading to final disposition: 1) disposal, 2) preprocessing and disposal, or 3) preprocessing, resource recovery, and disposal.

Neglecting open dumping, the sanitary landfill is the most widespread method of waste disposal currently used in the U.S. Although this method does require expenditures on heavy equipment, such as compactors, scrapers, and graders, the major cost for most communities is the cost of land. Because of recent restrictions on and requirements for landfills, the availability of suitable sites has shrunk. The reluctance of property owners to sell acreage for use as a landfill and their resistance to having a landfill adjacent to their properties further constricts supply. Additional processing to achieve more size reduction and more resource recovery will extend the life of sanitary landfills.

Processing and disposal, the second major alternative, involves shredding the waste stream prior to disposal. The size reduction achieved by shredding is substantial. For instance, a sanitary landfill with an expected life of 20 years designed to handle 1,000 tons per day requires about 31 percent more land than does a landfill of the same capacity at which the wastes are shredded prior to disposal. Additional size reduction can be achieved by incineration, after the waste has passed through a one-stage shredding operation. The residue remaining is landfilled; it represents about 10 percent by volume and about 25 to 35 percent by weight of the incoming waste stream (Levy and Rigo, 1976, p. 26).

The third major alternative available to municipalities is to process the waste stream, recover certain of the resources, and dispose of the remainder. The basic processing step is to shred the wastes. Resource recovery connotes both retrieval of the glass, ferrous, and aluminum fraction for recycling and the recovery of the energy content of the combustible fraction. The two methods used to recover energy from the waste stream are: 1) air classification which separates the "light" (combustible) fraction from the "heavy" (inorganic) fraction to produce a refuse-derived fuel (fluff RDF), and 2) incineration to generate steam. The steam is a more valuable product than fluff RDF, but requires more processing to make it so.

Materials recovery takes place at several points following the shredding operation. In plants that produce a fluff RDF, the ferrous portion is magnetically separated prior to and just after air classification while the glass and aluminum fraction is separated and recovered after the waste stream has been air classified. For the incineration processes, we assume that the ferrous, glass, and aluminum fractions are separated and recovered prior to incineration. Disposal of the wastes remaining following resource recovery operations is usually by sanitary landfilling.

Table 2 shows the resource recovery facilities in operation in 1976 across the nation. Quite obviously, most solid wastes do not enter resource recovery facilities but are directly disposed of.

TABLE 2. MIXED-WASTE RESOURCE RECOVERY FACILITIES IN OPERATION (SUMMER 1976)

Location	Type	Capacity (tons per day)	Products/markets	Startup date
Altoona, Pennsylvania	Compost	200	Humus	1963
Ames, Iowa	RDF	400	RDF, Fe, Al	9/75
Blytheville, Arkansas	Incineration	50	Steam/process	11/75
Braintree, Massachusetts	Incineration	240	Steam/process	1971
Chicago, Illinois (Southwest)	Incineration	1,200	Steam/industrial park	1963
E. Bridgewater, Massachusetts	RDF	160	RDF/utility	1974
Franklin, Ohio	Wet pulp	150	Fiber, Fe, glass, Al	1971
Groveton, New Hampshire	Incineration	30	Steam/process	1975
Harrisburg, Pennsylvania	Incineration	720	Steam/sludge drying	1972
Merrick, New York	Incineration	600	Electricity	1952
Miami, Florida	Incineration	900	Steam	1956
Nashville, Tennessee	Incineration	720	Steam heating & cooling	7/74
Norfolk, Virginia	Incineration	360	Steam/navy base	1967
Oceanside, New York	Incineration	750	Steam	1965/74
Palos Verdes, California	Methane recovery		Gas utility & Fe	6/75
St. Louis, Missouri	RDF	300	RDF coal-fired utility	1972
Saugus, Massachusetts	Incineration	1,200	Steam/process	4/76
Siloam Springs, Arkansas	Incineration	20	Steam/canning industry	9/75
S. Charleston, West Virginia	Pyrolysis	200	Gas, Fe	1974

Source: L. B. McEwen, Jr., *Waste Reduction and Resource Recovery Activities; A Nationwide Survey*. Environmental Protection Publication SW-142, Washington, 1977, p. 2.

SOLID WASTE MANAGEMENT OPTIONS

The solid waste management options represented in the process model include the major alternatives available to municipalities. These alternatives can, as shown in figure 1, be divided into six broad solid waste management strategies:

1) sanitary landfill,

2) mandatory source separation-sanitary landfill,

3) mandatory source separation-preprocessing-sanitary landfill,

4) mandatory source separation-preprocessing-resource recovery-sanitary landfill,

5) preprocessing-sanitary landfill, and

6) preprocessing-resource recovery-sanitary landfill.

The six strategies represent combinations of four options (santiary landfill, mandatory source separation, preprocessing, and resource recovery. Table 3 identifies the choices that the decision maker has within each option. These options represent the majority of those currently available to municipalities although, as shown in table 2, the experience with most is limited.

TABLE 3. SOLID WASTE MANAGEMENT OPTIONS

Sanitary landfill
Mandatory source separation
Paper recovery
Glass recovery
Ferrous recovery
Aluminum recovery
Preprocessing
Shredding
Incineration
Resource recovery
Glass recovery
Ferrous recovery
Aluminum recovery
Refuse-derived fuel
Steam

Sanitary Landfill

The sanitary landfill is currently the most common method of waste management. The location of the landfill is critical--an attempt is usually made to locate it so that the externalities imposed on residents of the municipality are minimized: the heavy truck traffic, the noise of heavy machinery, the dust, and the noxious odors all contribute to a desire on the part of residents to have the landfill located as far away from themselves as possible. The geology of the landfill site must also be selected or altered so that the leachate (runoff water) does not contaminate water supplies.

The landfill in our model has a lifetime of 20 years. The site has twice as many acres as are actually needed for disposal; this helps minimize the externalities mentioned above and provides room for access roads for garbage trucks and other vehicles. Each acre used for disposal is dug out to a depth of 25 feet and can hold 20,000 tons of waste, when properly processed by compactors, scrapers, graders, and truck-type tractors that constitute the landfill's capital equipment. In the usual procedure, a load of waste is deposited in the pit, compacted, leveled and then covered with two or three feet of earth. The layers of dirt help prevent odors, rodent infestations, and unsightliness--major complaints leveled against the open dumps still in use in some areas of the country.

Properly managed, the site can be reclaimed for other uses--usually recreational--at the end of its useful life as a landfill. Once a site is closed, it sits idle for a period of time to allow decomposition and settling to take place. Since the site does have alternative uses, the original investment in the land can be recouped. Thus, the true cost of the land to the municipality is the cost of the money used to purchase the land, i.e., the interest rate.

Mandatory Source Separation

Once the most valuable wastes have been skimmed, the remaining wastes are collected from their points of generation: households, businesses, and other commercial establishments. It is at this point that mandatory source separation can take place. There are two major types of separate collection programs, one in which newspapers only are picked up, the other in which newspapers and mixed cans and glass are collected.

Newspapers are the easiest component of residential solid waste to separate and to maintain in a relatively clean condition, i.e., free from contaminants such as moist food wastes. The newspapers/mixed cans and glass program requires each participant to separate his wastes into three categories: newspapers, cans and glass, and all other wastes. The time and storage requirements are greater than those for the newspaper program, but the possibility of diverting the large can and glass fraction of municipal solid wastes could prove economically attractive enough for the city to mandate such a program. The attractiveness must be tempered, however, with the realization that the more time and effort the program imposes on participants, the greater the likelihood that people will not cooperate.

The success of mandatory source separation programs depends on four factors (EPA, 1977): 1) the availability of long-term markets for the recovered materials, 2) an ongoing publicity campaign to maintain the public's awareness of the program, 3) careful planning, and 4) an antiscavenger ordinance that prohibits pickup of the separated materials by any party other than the municipality or the municipality's contract hauler. Success can be partially measured by the participation rate--the percentage of residents in the collection area who place separated materials out for collection. Because many of the incremental collection costs aresfixed, increasing participation in the program means lower costs and usually greater revenues to offset those costs.

This is plainly shown when comparing the Marblehead and Somerville separate collection programs. During the first nine months of 1976, the Marblehead program with a participation rate of 75 to 80 percent resulted in net savings[1] of around $2,857 per month. Approximately 26 percent of the total waste stream (by weight) was diverted from disposal. In the Somerville program, on the other hand, participation was much lower during the same period of time so that net savings averaged about $333 per month. Only 8 percent of Somerville's waste stream was diverted. Eliciting the community's support and cooperation, then, is probably the key factor in determining the success or failure of a separate collection program. Details of these programs can be found in several publications (EPA, 1977; McEwen, 1977; Resource Planning Associates, Inc., 1976).

The future of such source separation programs appears promising. They involve smaller capital expenditures than do other methods of processing municipal wastes. There are fewer uncertainties associated with this approach than there are with other more capital-intensive methods. Also, with disposal sites becoming increasingly scarce and more expensive, mandatory source separation programs offer a relatively inexpensive way to extend the life of sanitary landfills.

Refuse-Derived Fuel Plants

While shredding can reduce landfill costs to a certain extent, the municipality is still disposing of a large proportion of its solid wastes (between 80 and 90 percent, even if the glass, ferrous, and aluminum fractions are recovered). In cases where landfill costs are prohibitive, or where energy prices are favorable, the municipality may find that some form of energy recovery is necessary to keep disposal costs at a manageable level. There are two routes a municipality can take to recover energy from its solid wastes: 1) produce a refuse-derived fuel (RDF), or 2) incinerate the wastes to generate steam. This section considers the former alternative; incineration is discussed in a later section.

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[1] Net savings are defined as revenues plus avoided disposal costs minus incremental collection costs.

The RDF options produce a fluff RDF consisting of combustible particles with an average size of one inch and with most of the dense organics and inorganics removed. It is primarily used as a supplementary fuel in coal-burning facilities. Typical processing operations are depicted in the flowchart of figure 2.

The waste stream is first shredded to an average particle size of four to eight inches. A portion of the ferrous metals is recovered by magnetic separation and the remaining wastes are air classified. The light fraction is passed through a trommel to separate glass fines and any remaining heavies. The wastes that do not fall through the trommel are then shredded again to produce particles ranging from 1/4 inch to 2 inches in size and with a Btu content of about 5,000 Btu per pound. The fluff is then piped pneumatically to a storage location and then to a coal-fired boiler, where it constitutes between 10 and 20 percent of the charge.

If no materials recovery is being undertaken, the heavy fraction, including the materials that fell through the trommel, is landfilled. However, if any materials recovery is to take place, the heavies from the air classifier and the trommel undergo a second stage of magnetic separation. Aluminum is recovered (if desired) by eddy current separation and glass (if desired) by froth flotation. Any remaining residue is landfilled.

This procedure can recover approximately 90 percent of the light fraction in the form of fluff RDF. This would, of course, mean a considerable savings in disposal costs, since the lights constitute about three-fourths of municipal solid wastes. Adding materials recovery modules to the basic RDF system will also reduce disposal costs.

Shredding and Materials Recovery

Under certain circumstances, such as high land prices or favorable secondary materials prices, it may be more economical for a municipality to process its waste stream prior to disposal or to undertake the recovery of certain materials, rather than simply landfill all of it wastes. The options shown in figure 1 give the municipality this sort of flexibility in determining its least-cost waste management program.

The flowchart of figure 3 illustrates the shredder options. The first stage of this set of alternatives is to pass all wastes through a shredder. The size reduction achieved by shredding is considerable; the wastes leaving the shredder have an increased density, which means that larger quantities of waste can be landfilled in the same amount of land compared with unprocessed wastes. After shredding, the density of the waste

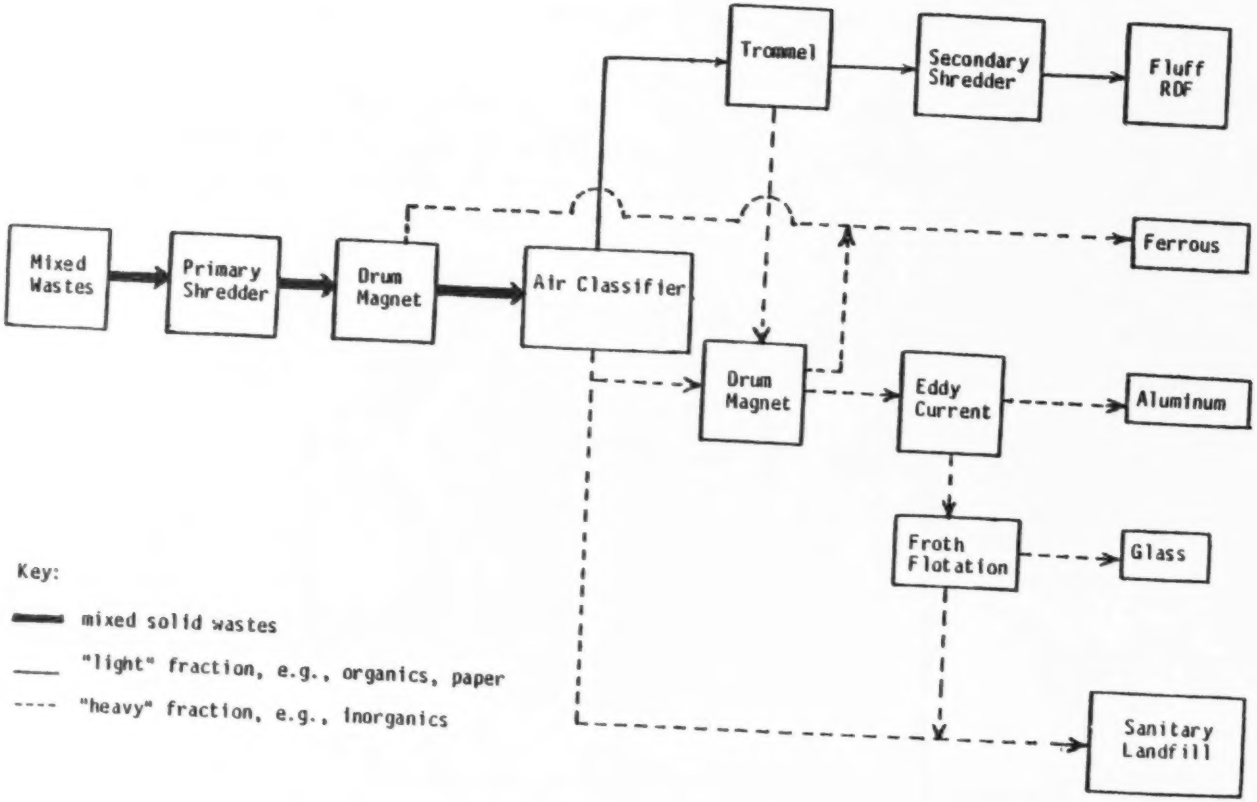
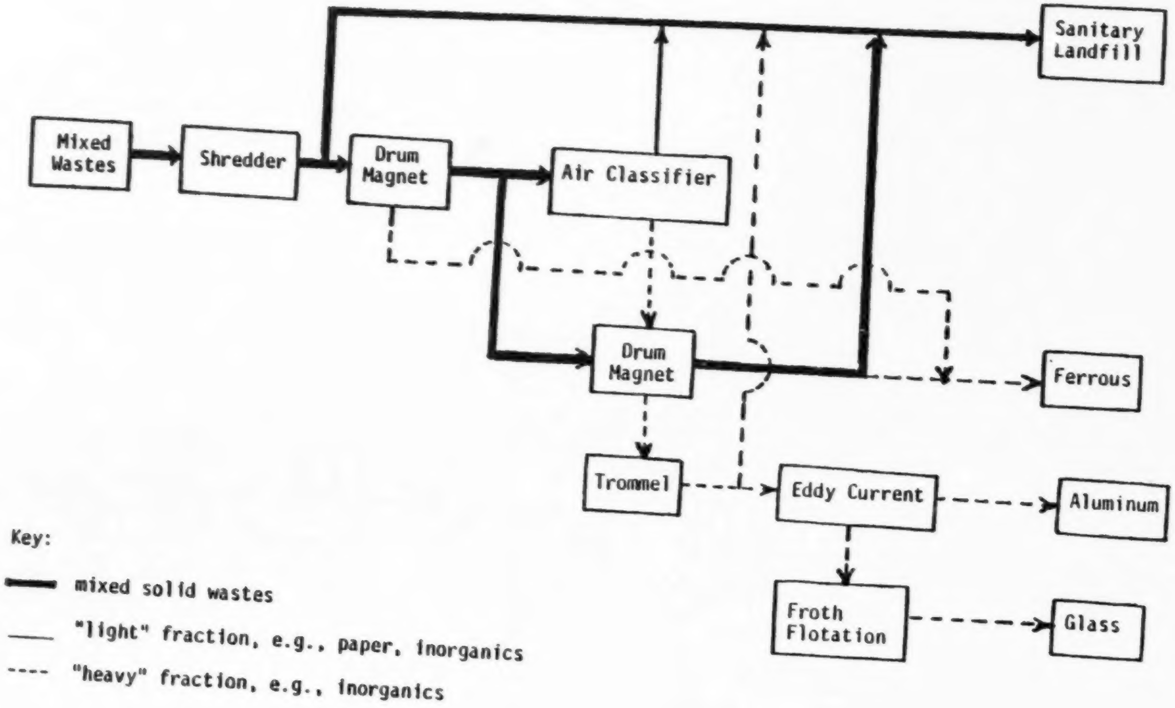

Mixed Wastes
Primary Shredder
Drum Magnet
Air Classifier
Trommel
Secondary Shredder
Fluff RDF
Ferrous
Drum Magnet
Eddy Current
Aluminum
Froth Flotation
Glass
Sanitary Landfill
Key:
mixed solid wastes
"light" fraction, e.g., organics, paper
"heavy" fraction, e.g., inorganics

Figure 2. Solid waste processing in refuse-derived fuel plant.


Mixed Wastes
Shredder
Drum Magnet
Air Classifier
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Key:
mixed solid wastes
"light" fraction, e.g., paper, inorganics
"heavy" fraction, e.g., inorganics

Figure 3. Solid waste processing by shredding.

stream is about 30 percent greater than that of unprocessed waste, i.e., about 26,000 tons of shredded waste can now be landfilled on each acre of land. The result is to extend the life of an existing landfill or to reduce the number of acres required to dispose of a fixed amount of waste. The shred-dispose option, one of two process-dispose options noted in the overview above, is represented in the flowchart by the heavy arrow connecting the boxes labeled "shredder" and "sanitary landfill."

If any type of materials recovery is to be undertaken, the shredded wastes first move on a conveyor belt under a drum magnet, the first stage of ferrous metals separation. If no other materials are being recovered, the shredded wastes are passed under a second drum magnet; the wastes are landfilled and the recovered ferrous scrap undergoes cleaning and some additional processing prior to sale. Magnetic separation can recover approximately 90 percent of the ferrous metals in the waste stream. It is a proven tehnology. The recovered materials can be sold to detinners or directly to some steel producers.

The processing sequence is slightly altered if glass or aluminum is to be recovered in addition to the ferrous metals. As shown in the flowchart, after passing under the first drum magnet the shredded waste stream is air classified by dumping it into an upward-moving column of air. Basically, the air classifier divides the waste stream into a "light" fraction consisting of organics, such as paper, food, and yard wastes, and a "heavy" fraction composed of inorganics, such as metals, glass, dirt, and rocks, and dense organics, such as wet food and yard wastes. The light fraction is landfilled. The "heavies" pass under a second drum magnet for additional recovery of ferrous metals, then into a trommel, a cylindrical revolving screen that allows "heavy" particles smaller than four inches to drop through for further processing. Particles remaining in the trommel are landfilled.

The feed to the glass or aluminum separation modules consists of glass, aluminum, rocks, dirt, bones, some ferrous metals, heavy organics and some other inorganics (Levy and Rigo, 1976). These modules are complementary--separation of aluminum leaves a fraction that is rich in glass, and vice versa. However, as shown by the flowchart, we allow for the recovery of one, the other, or both. If glass and aluminum are to be recovered, the remaining heavies are passed on a conveyor belt over a linear motor. Electric current in the motor creates a magnetic field that induces an eddy current in any conductor (metallics) passing through the field. The induced current in the conductors opposes that being generated by the linear motor strongly enough to knock the conductors off the belt. Eddy current separation, also known as the "aluminum magnet," can recover about 70 percent of the aluminum fraction.

Glass cullet is separated from the remaining stream of heavies using froth flotation. In this process the stream is treated with a reagent that gives glass "hydrophobic surface characteristics," i.e., that tends to make it float. This stream is then fed into the flotation chamber, which contains a liquid undergoing constant agitation by rotors. The air bubbles produced by the agitation attach themselves to the glass particles, which then float to the surface. The resulting froth is skimmed and cleaned. The product is a clean mixed cullet, or "sand," that can be used in small amounts in glassmaking. Compared to color-sorted cullet, however, the product of this model is a low quality aggregate mainly suitable for use in making brpcks or "glassphalt."

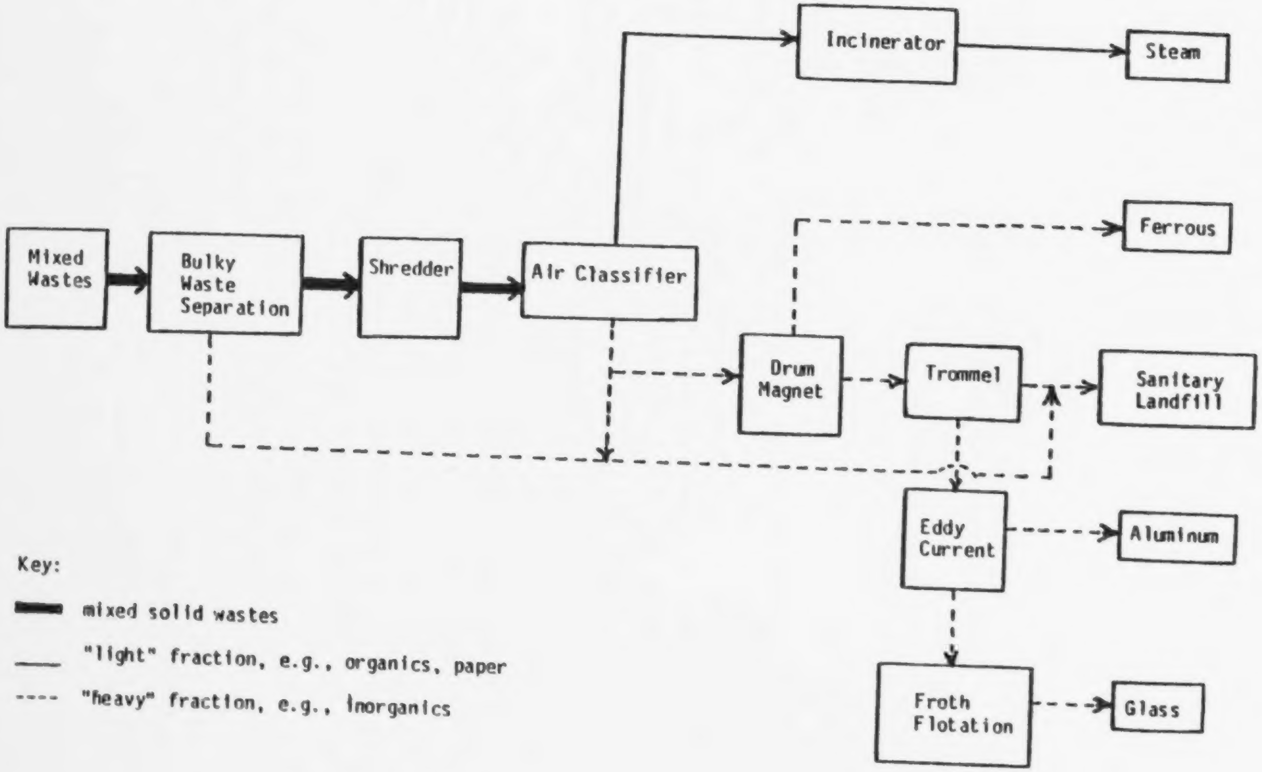
This system can recover about 66 percent of the glass in the solid waste stream. The residue remaining in the flotation chamber (and which does not float to the surface) is removed and landfilled.

Incineration

Incineration is the second major form of energy recovery available to municipalities and included in the model. Two types of incinerators are available to municipalities, depending on their capacity requirements. We assume that a municipality processing less than 500 tons per day will use the small modular, or package, incinerators. These are available in capacities of 25 and 50 tons per day and can be connected in series to achieve the desired capacity. For those cities requiring processing capacity between 500 and 3,000 tons per day, the larger waterwall incinerators are available. The combustion chambers of these incinerators are enclosed by closely-spaced water-filled tubes that recover heat from the burning waste. Steam is generated by built-in recovery boilers, which also reduce the temperature and volume of the exhaust gases.

Solid waste processing by incineration is depicted in the flowchart of figure 4. One feature of this flowchart that bears noting is that any materials recovery that occurs takes place on the "front end," i.e., prior to incineration. While materials recovery from the incinerated residue is possible, the recovered materials, especially the ferrous scrap, are fundamentally different from the product recovered prior to incineration. Incineration of tin-plated steel causes the tin to fuse with the steel, thus making detinning impossible. Incinerator bundles, as they are called, are only suitable for use as scrap inputs to foundries. To make the materials recovered by a municipal waste mangement program homogeneous, regardless of the option selected, we employed "front end" processing of wastes destined for incineration.

In the processing sequence depicted in the flowchart, bulky wastes, e.g., appliances, are manually separated from the waste stream prior to shredding. This applies only to municipalities using the modular incinerators, since the shredders feeding these incinerators are too small to process large, bulky wastes. After shredding, the waste stream is air classified and divided into light and heavy fractions. The light fraction is fed into the furnace by spreader stokers that move the wastes across the combustion chamber to a traveling grate. This is a semi-suspension


Mixed Wastes
Bulky Waste Separation
Shredder
Air Classifier
Incinerator
Steam
Ferrous
Drum Magnet
Trommel
Sanitary Landfill
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Aluminum
Froth Flotation
Glass
Key:
mixed solid wastes
"light" fraction, e.g., organics, paper
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Figure 4. Solid waste processing by incineration.

incineration process in which the waste is partially burned while falling through the chamber and finishes burning while lying on the grate. Air is introduced below (underfire air) and above (overfire air) the grate to promote the mixing of gases and to ensure complete combustion. The ash and any incinerated inorganics are landfilled. The ferrous, aluminum, and glass in the heavy fraction are removed (if at all) by magnetic separation, eddy current separation, and froth flotation, respectively. All unrecovered residue is landfilled.

Incineration reduces raw waste to approximately 25 to 35 percent of its original weight, including the glass, ferrous, and aluminum fractions. The steam generated is about three times more valuable than fluff RDF; this occurs because the incineration option includes an additional processing step (combustion), which increases the cost. Approximately 59 percent of the energy content of the original waste stream is recovered in the form of marketable steam (Levy and Rigo, 1976).

SOLID WASTE MANAGEMENT COSTS

The solid waste management costs for the options identified in the previous section are discussed below. The costs were primarily derived from data developed for the Kansas City Metropolitan region in a 1977 study by Franklin Associates and Black & Veatch, Consulting Engineers. In that study costs were determined from contacts with equipment suppliers and from operating RDF plants for 500 and 1,000 tons per day with materials recovery, and shredding plants with materials recovery. Extrapolations were made for other plant capacities. Because of the limited data, mandatory source separation is not covered.

Although it is conceivable that in a few areas of the country, plants larger than 3,000 tons per day may be the best option, those plants were not considered for this analysis. Plants larger than 3,000 tons/day have special siting problems primarily due to the heavy truck traffic in and out of the plants, and high transportation costs. They cannot generally be treated as simple extensions of the lower capacity plants.

Three basic types of mixed solid waste (MSW) plants are considered in this analysis. One is a plant which genrates a "fluff" RDF to be burned as a supplementary fuel in a coal-burning facility and which also recovers some combination of steel, aluminum, and glass for recycling. Another type of plant simply shreds the solid waste for landfilling and has the capacity for adding material recovery facilities. The third type is an incineration facility that generates steam.

The RDF plants are generally similar to the facilities in Ames, Iowa, Southwest Supplementary Fuel Processi g facility in Chicago, and the Americology plant in Milwaukee. The shredding plant is similar to the Recovery I facility in New Orleans.

The RDF and shredding plants were evaluated at capacities of 500, 1,000, 2,000, and 3,000 tons of solid waste per day. The incineration facilities were evaluated at capacities of 50, 200, 500, 1,000, and 2,000 tons per day. For each of the capacities, costs were developed for plants with no material recovery, steel recovery only, steel and aluminum recovery, steel and glass recovery, and steel, aluminum, and glass recovery. Plants with aluminum and/or glass recovery without steel recovery were not considered since it is essential to remove the steel from the waste stream to successfully remove the aluminum and glass.

Sanitary Landfill

The initial per acre cost of the land depends on several things: alternative uses of surrounding land, distance of the site from population centers, population density of the region, etc. They are also undoubtedly influenced by a host of region-specific factors, such as the growth rates of industry and population in the region, climate, employment, etc. A preliminary estimate of landfill costs was developed using data on landfill practices in 17 communities (table 4). The 1975 populations of these cities ranged from 21,000 to 368,000 and represented five of the 10 size categories used in the process model (table 5). Data on the cost and size of the landfill sites were available for 15 of the 17 cities (two municipalities were leasing the sites). From these data, the per acre price of the land was calculated; it ranged from $163 to $10,000 per acre. A simple functional form relating price to the population and to the square of the population was fitted to these data using ordinary least squares:

$$\mathrm{LPRICE} = \underset{(0.47)}{3.1461(\mathrm{POP})} + \underset{(2.01)}{0.0492(\mathrm{POP})} \quad \text{where}$$

LPRICE = price per acre

POP = population (in thousands).

The t-values for the coefficient estimates are in parentheses. The R for this function was .76. The predicted land values for each representative city size in the model are given in table 6. The estimated land prices for the larger and smaller city sizes tend to be extremely large and small, respectively. This occurs because we extrapolated beyond the range of our data--a risky procedure at best, but one that is superior to the arbitrary assignment of "reasonable" values to those out-of-range cities.

Refuse-Derived Fuel Plants

The RDF plants for which costs were developed are complete systems. The items, not all itemized in the analysis, but which are included are listed below.

Truck scales
Tipping floor conveyors
Primary and secondary shredders with necessary input and output conveyors. (Only 50 tons per hour or larger shredders were considered.)
Trommel screen--used only when there is metal or glass recovery
Air classifier subsystem

TABLE 4. DATA USED TO ESTIMATE PRICE OF LAND FUNCTION

	Landfill data			
City	Total land expenditures (10^3\$)	Size (acres)	Price (\$/acre)	Population, 1975 (10^3 persons)
Cape Girardeau, Mo.*	----	60	---	31
Fairfax County, Va	85	81	1049	21
Fresno, Ca.	190	200	950	177
High Point, N.C.	60	60	1000	67
Independence, Mo.	94	44.7	2103	111
Joplin, Mo.	165	180	917	39
Kenosha, Wis.	40	33	1212	80
Lancaster, Va.	108	215	502	150
Madison, Wis.	56	14	4000	168
Madison, Wis.	50	24	2083	168
Nashua, N.H.	295	295	1000	62
Norfolk, Va.	83	83	1000	287
Odessa, Tex.*	245	1500	163	78
Raleigh, N.C.	283	137	2066	111
Richardson, Tex.*	----	227	----	57
Toledo, Oh.	680	68	10000	368
Topeka, Kans.	65	160	406	119

* Landfill site was leased.

Source: EPA, Office of Solid Waste Management Programs.

TABLE 5. DISTRIBUTION OF CITIES, BY SIZE CATEGORY, 1976

Size categories (10^3)	Number of places*	Population		
		Total (10^3)	Percent of U.S. population*	Average city size (10^3)
1,000 +	6	19,748.6	9.2	3,291.4
500 - 1,000	20	13,738.2	6.4	686.9
250 - 500	30	10,947.6	5.1	364.9
100 - 250	100	15,026.1	7.0	150.3
50 - 100	240	17,602.0	8.2	73.3
25 - 50	520	18,890.0	8.8	36.3
10 - 25	1385	22,539.2	10.5	16.3
5 - 10	1839	13,738.2	6.4	7.5
2.5 - 5	2295	8,586.4	4.0	3.7
Less than 2.5	627	858.6	0.4	1.4
Total (Average)	7062	141,674.9	66.0	20.1

* 1970 values. The 1976 population was used in calculating the total population and average city size for each category.

Source: U.S. Bureau of the Census, Statistical Abstract of the United States: 1977. (98th edition) Washington, D.C., 1977, Table 20.

TABLE 6. ESTIMATED PRICE OF LAND USED FOR SANITARY LANDFILL FOR REPRESENTATIVE CITIES

Size Category	Average population (10^3 person)	Land price ($/acre)
1,000 +	3291.4	543354.1
500 - 1,000	686.9	25375.2
250 - 500*	364.9	7699.1
100 - 250*	150.3	1111.4
50 - 100*	73.3	495.0
25 - 50*	36.3	179.0
10 - 25*	16.3	64.4
5 - 10	7.5	26.4
2.5 - 5	3.7	12.3
< 2.5	1.4	4.5

* Estimates for these city sizes fall within the range of the data from which the coefficients were estimated.

Pneumatic RDF delivery system to storage and to boiler
Dust collection system
RDF storage system
Control panels
Residue conveyors and bins
Coal burner modifications
Truck loading facilities
Ferrous metal recovery subsystem consisting of two stages of magnetic separation for each processing line and the associated conveyors and bins
Aluminum recovery subsystem consisting of one aluminum magnet per processing line and the associated conveyors and bins
Glass recovery subsystem (froth flotation)
Delivery and electrical and mechanical installation of all equipment
Mobile equipment
Supplies and furniture

Some of the assumptions made for this cost analysis are:

1. The fuel generated is "fluff" RDF.

2. Costs for plants as a function of capacity were determined by the function:

$$\frac{Ca}{Cb} = \left(\frac{Sa}{Sb}\right)^n$$

where C is plant costs, S is plant capacity, and n is 0.8 for all costs except labor and land. For labor and land the exponent is 0.6. These exponents were chosen on the basis of costs for the 500 and 1,000 TPD plants.

3. Land costs for RDF plants are calculated at $50,000/acre.

4. The buildings (reinforced concrete) are large enough to permit the addition of material recovery subsystems.

5. Interest during construction is equal to 6 months of interest on the total capital investment. (It is assumed that construction time is 2 years, during which time part of the capital may be reinvested.)

6. Startup costs are equal to the operating and maintenance costs for one year. (This is to operate the plant during shakedown, when there is little or no revenue expected.)

7. Labor costs are based on Kansas City, Missouri rates and include 40 percent for fringe benefits, overtime, etc.

8. All RDF plants are assumed to process solid waste 2 shifts per day, 300 days per year with an 85 percent availability. The availability factor is to allow for routine maintenance and breakdowns. System costs were not developed on the premise of providing standby process lines for use in the event of breakdown. However, diverters and RDF trailers are included to be used in the event of power plant breakdown.

Shredding and Materials Recovery

The analysis for the shredding and shredding with material recovery plants is similar to the RDF plants. However, only one stage of shredding is needed and facilities and equipment for energy recovery are not included. In the plant with no material recovery or with only steel recovery the air classifier system is not needed.

Incinerators

Cost for the modular incinerator are given for 50, 200, and 500 tons of solid waste per day. The data for the 50 and 200 TPD plants without materials recovery came from the Franklin Associates Ltd. report; the 500 TPD data were obtained by extrapolation. The costs for recovering materials were estimated, based on the previously submitted RDF data. There are no known municipal modular incinerators in operation where materials are mechanically separated prior to incineration.

The mechanical processing consists of single stage shredding, air classification, magnetic separation, aluminum magnet separation, and glass separation by screening and froth flotation. Because of the smaller size requirement for the shredders, large bulky items would need to be handpicked from the waste. (In order to shred bulky wastes, 50 ton per hour or larger shredders would be required.) Included are cost estimates for truck scales, mobile equipment for feeding the solid waste into the incinerators, and delivery and installation of all equipment. The systems for which cost estimates are made include single lines of mechanical processing and two parallel incinerator units for the 50 TPD plants, four for the 200 TPD plant, and eight for the 500 TPD plant. Each incinerator is equipped with a steam boiler which generates about 3 pounds of low pressure steam per pound of solid waste. Steam lines are provided to a user approximately 500 feet away from the boiler.

It is assumed that incinerators would operate continuously, with the mechanical processing being done eight hours per day, five days per week. Amortization costs are calculated at 7 percent and 20 years.

It is assumed that incinerators would operate continuously, with the mechanical processing being done eight hours per day, five days per week. Amortization costs are calculated at 7 percent and 20 years.

The semi-suspension cost data were derived from actual contract costs of the 1,000 TPD recycle energy system under construction in Akron, Ohio.[2] The process in Akron consists of coarse single stage shredding of the solid waste; combustion of the light fraction in semi-suspension fired waterwall boilers; recovery of ferrous metals; and future recovery of glass and aluminum. The aluminum magnet and glass screening and froth flotation system costs were added from the Franklin Associates Ltd. data.

In the semi-suspension process, the shredded light fraction is approximately 50 percent burned while falling through the flame, thus improving the boiler efficiency over mass burning. The remainder is burned on a grate. The energy product is steam which is distributed to steam customers which must be located within a mile or two of the plant. In the Akron plant, steam generation is estimated at 4 pounds per pound of solid waste. After the steam for in-house use and distribution system losses is deducted, it is expected that 3.2 pounds steam per pound of solid waste will be available for sale.

Amortization costs for the equipment and buildings are calculated at 7 percent and 20 years.

Average availability of the modular plant was assumed to be the same as for the semi-suspension plant, that is, 85 percent, 350 days per year. It is assumed that the incinerator will produce saturated steam at 560 psig continuously and that the mechanical processing equipment will operate 5 days per week, 8 hours per day.

PROCESS MODEL

The solid waste management options and their costs are included in a solid waste management process model (SWMPM) along with relevant waste generation rates and materials prices. The decision maker, confronted with an exogenously established flow of solid wastes is assumed to select the solid waste management option that minimizes the cost of waste management. The analysis is done for the average city sizes shown in table 5. The flow of operations is SWMPM is presented in figure 5 and discussed below.

Enter Secondary Materials Prices

The first step in the operation of the model is to determine the set of secondary materials prices that will confront each representative

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[2] Hileman, G. P., and F. B. Pyle, "Recycle Energy for Central Heating and Process Steam," presented to International Heating Association, 1977.

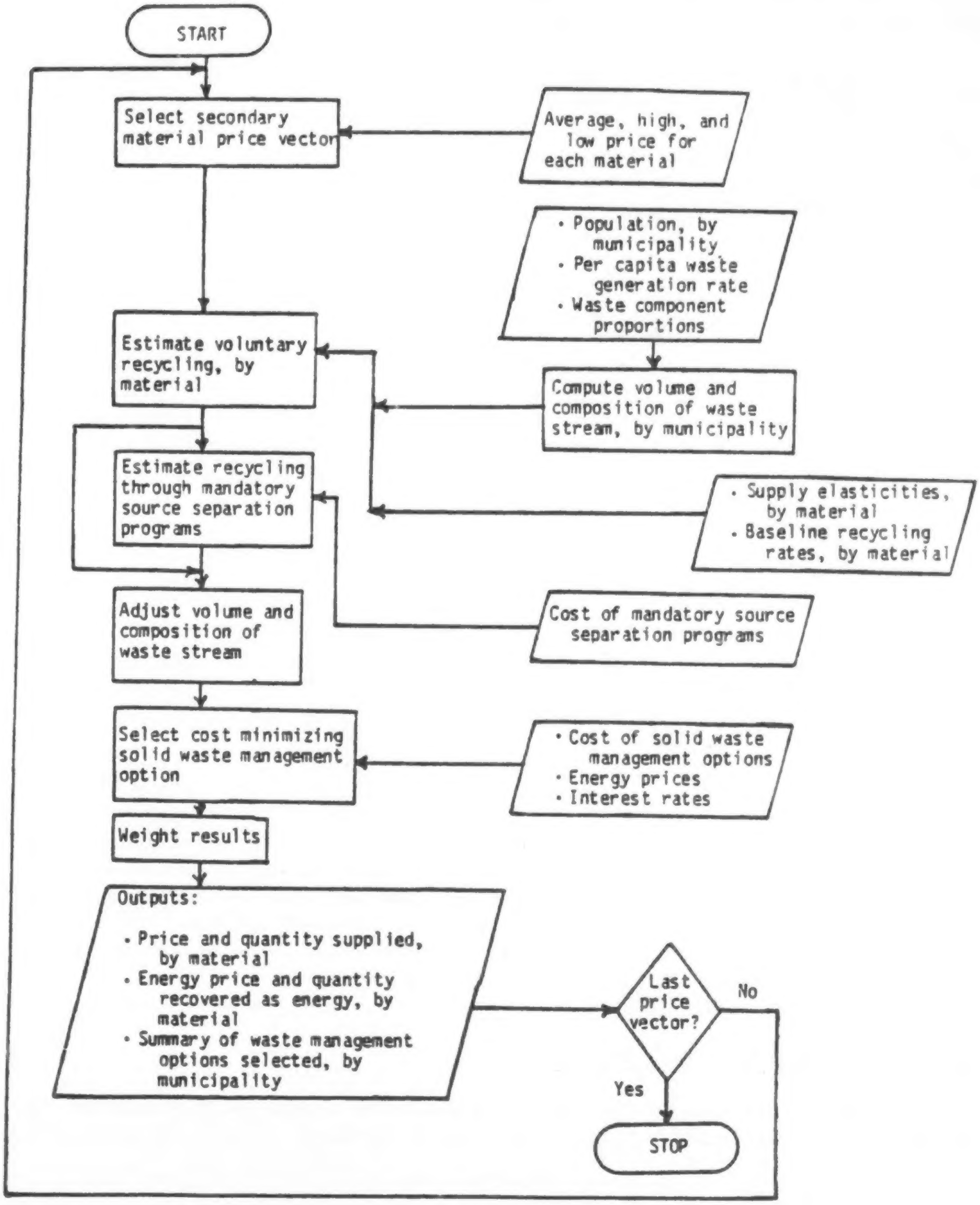
START
Select secondary material price vector
Average, high, and low price for each material
• Population, by municipality
• Per capita waste generation rate
• Waste component proportions
Estimate voluntary recycling, by material
Compute volume and composition of waste stream, by municipality
Estimate recycling through mandatory source separation programs
• Supply elasticities, by material
• Baseline recycling rates, by material
Adjust volume and composition of waste stream
Cost of mandatory source separation programs
Select cost minimizing solid waste management option
• Cost of solid waste management options
• Energy prices
• Interest rates
Weight results
Outputs:
• Price and quantity supplied, by material
• Energy price and quantity recovered as energy, by material
• Summary of waste management options selected, by municipality
Last price vector?
No
Yes
STOP

Figure 5. Flow of operations in the supply model.

municipality. Elements of this set are drawn from the universe of "high" and "low" deviations from the average price of each material. A total of 16 unique price vectors[3] is selected by the model; each drives the model and the resulting price-quantity pairs constitute the data set.

Selection of a price vector has two major effects: 1) for each material the percentage change of the high or low price from the average price elicits some percentage change in the level of voluntary source separation through an elasticity calculation, 2) secondary material prices obviously impact the conomics of municipal solid waste management by altering the potential revenues available from recovering and selling the materials. The rationale for selecting the range of price variation and the exact method used to vary the prices are discussed in the section on Price Variation.

Calculate Amount and Composition of Solid Waste

For each representative municipality, the total waste generated each year is the product of the population and the per capita waste generation rate. We apply a vector of fixed material proportions to decompose this total into the five material components used in the model: paper, glass, ferrous materials, aluminum, and all other wastes.

Estimate Extent of Voluntary Source Separation

At this point we estimate the amount of each secondary material that is voluntary separated at its source of generation, because the level of this activity directly affects the amount of waste collected and disposed by the municipality. Voluntary source separation activities are influenced by the prices of secondary materials. Thus, each material is represented by a baseline recycling rate that is a function of the average material price; any deviations from this price alter the baseline recycling rate through a supply elasticity. The resulting percentage change in quantity supplied is applied to the amount of that waste material to determine the absolute level of voluntary source separation taking place.

Estimate Effects of Mandatory Source Separation

As explained above, two programs are available to municipalities, one involving separate collection of newspapers, the other for collecting newspapers and mixed cans and bottles. The costs of both programs depend on their efficiency in recovering the relevant materials. In this and the next step (the cost minimization routine) the model investigates three alternatives: 1) all municipalities opt for separate collection of

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3. The number of possible unique combinations of high and low prices for four materials is 2 . The price of the fifth material is held constant (at zero), since no materials are recovered from "all other" waste. Energy is recovered, and we account for it in the model, but we did not need to know the own- and cross-price elasticities of the supply of energy from solid wastes, so its price was also held constant.

newspapers, 2) all municipalities opt for separate collection of newspapers and cans and bottles, 3) no municipality engages in separate collections. waste management; the least-cost alternative is then chosen. The municipality in effect has 48 waste management strategies to choose from.[4]

Revise Waste Stream Composition

The amount of each material in the waste stream is adjusted to reflect the quantities diverted by voluntary and mandatory (if any) source separation activities.

Minimize Processing and Disposal Costs

The municipality must process and dispose of all remaining solid wastes by using the least-cost mix of options available to it. The cost of each option is a nonlinear function of the amount of waste to be processed. Revenues are derived from the sale of secondary materials and energy. Unrecovered wastes are disposed of at a cost that also varies with the amount. This is the general form of the net cost function that is minimized by the nonlinear optimization algorithm:

$$\min_{k} \left[\min_{i} \left\{ a_{1i}[X(1-R_k)]^{a_{2i}} + a_{3i}[X(1-R_k)(1-E_i)^{a_{4i}} - X(1-R_k)E_iP \right\} + X R_k C_k - X R_k P \right]$$

$$\text{for } k = 1,2,3 \qquad i = 1,\ldots,16$$

subject to

$$X(1-R_k)E_i + X(1-R_k)(1-E_i) + XR_k = X^* - V$$

where

X = total waste to be processed by the municipality

R_k = proportion of waste stream diverted by the k^{th} mandatory source separation program

E_i = proportion of waste stream recovered by the i^{th} basic option

P = price of recovered materials

---

[4] The 48 alternatives come from the 16 basic options, each applied in conjunction with the three separate collection options.

C_k = cost of the k^{th} mandatory source separation program

X^* = total waste generated in the municipality

V = amount of waste stream diverted by voluntary source separation

a_i = estimated cost coefficients.

The first term is the cost of processing all wastes (net of those diverted by a mandatory source separation program) by the i basic option; the second term is the cost of disposing of the wastes remaining after processing. These costs have three components: land, operating and maintenance, including labor, and capital. The third term is the revenues generated by processing wastes using the i basic option. The fourth and fifth terms represent the costs and revenues, respectively, of the k separate collection program. The constraint is that the amount recovered (first term) plus the amount disposed (second term) plus the amount diverted by mandatory source separation (third term) must equal the total amount of waste generated in a municipality less the amount that is voluntary recycled.

Outputs

Once the above steps have been performed for each representative city, the results are weighted by the number of cities in the U. S. in each size category. The outputs of primary interest are the price-quantity pairs constituting the data set. Other outputs include the amount of materials recovered as energy and a summary of the options selected by the municipalities for handling their solid wastes.

SUPPLY FUNCTIONS

Supply functions were estimated for three secondary materials--glass, ferrous, and aluminum, using the data generated by the process model presented above. Since paper is only recovered as a fiber under voluntary and mandatory source separation, its supply was estimated outside the model but incorporated in the model, as its recovery affects the energy content of the waste stream and the economics of resource recovery systems.

Price Variation

The model requires three prices for each material: the average, low, and high prices. Deviations above and below the average price are used to determine the amount of "front end" recylcing (i.e., source separation) that occurs. The municipality is confronted with combinations of the high and low secondary materials prices--16 in all.

This system of price variation is a 2^4 factorial design in which two prices for paper, two for glass, two for steel, and two for aluminum are tested in all combinations. The 16 resulting price vectors represent points at the 16 corners of the experimental region, which is a four-dimensional hypercube. Thus, the range of price variation determines the size of the experimental region over which the mathematical model of secondary materials supply is assumed to be valid. However, as the size of this region increases, the likelihood that the model is valid over the entire region decreases. Hence, the range over which the prices are varied is a critical factor in the estimation procedure. In determining the range of price variation, we started with average 1976 prices and considered the historical variation in secondary material prices along with the probable effects of the disposal charge. The values are shown in table 7.

TABLE 7. SECONDARY MATERIALS PRICES AND SUPPLY ELASTICITIES

	Price (dollars per ton)			Supply elasticity[*]	
	Low	Average	High	Low	High
Paper[+]	5.0	25.4	60.0	.4	1.7
Glass [§]	0.1	10.0	40.0	.1	.71
Ferrous metals [§]	9.0	39.0	69.0	.1	3.9
Aluminum	200.0	300.0	380.0	1.1	4.3
Energy ($/thousand Btu)					
RDF	0.5	---	1.5	---	---
Steam	1.2	---	3.6	---	---

[*] Estimates supplied by the Resource Conservation Committee.

[+] Prices developed from Official Board Markets. Since OMB quotes are delivered prices, they were multiplied by .5 to approximate prices paid to generators.

[§] Franklin Associates Ltd., Memoranda to EPA and ICF, February 17, 1978.

Supply Estimates

The data set generated by the process model consisted of 16 sets of secondary material quantities and prices. A function that was linear in the logarithms of its variables was fitted to these data using ordinary least squares. The functional form is given by

$$lnO_i = a_0 + a_1 lnP_1 + a_2 lnP_2 + a_3 lnP_3 + a_4 lnP_4 + a_5 lnP_5$$

where Q_i = the quantity of the i^{th} material recovered, i=2-4,

a_i = the regression coefficients,

P_1, P_2, P_3, P_4 = prices the municipality receives for the seondary materials, and

P_5 = price the municipality receives for recovered energy.

The resulting elasticity of supply estimates are shown below. They incorporate voluntary source separation elasticities (Table 7) along with the estimates of the response of municipalities to the price changes.

	Coefficients (t-statistics)					
	Paper	Glass	Steel	Aluminum	Energy	R2
Paper	1.7	0.0	0.0	0.0	0.0	---
Glass	0.022* (0.85)	0.190 (17.63)	0.136 (4.27)	0.120* (1.19)	0.014* (0.70)	.928
Steel	0.068 (2.56)	0.049 (4.43)	0.396 (12.13)	0.207 (2.01)	0.065 (3.05)	.882
Aluminum	0.050 (1.97)	0.044 (4.16)	0.246 (7.96)	1.102 (11.27)	0.051 (2.56)	.896
Energy	-0.123 (-28.23)	0.003 (1.76)	0.016 (2.93)	0.010* (0.59)	0.236 (68.01)	.995

*Not significant at $\alpha = .10$ level.

The estimated supply elasticities confirm the belief that the supply of secondary materials from the municipal solid waste stream is fairly unresponsive to price changes. The data confirm the interdependence of the supply of secondary materials from the municipal waste stream.

CONCLUSIONS

The combined use of process and econometric models provide a means for estimating the supply elasticities for products for which there is no adequate historical record or data base for use in a more positive approach. It can be used to make predictions of quantities supplied for sets of prices not used in the estimation (the new price vectors must fall within the experimental region, however). Because we are using a process model, the resulting data depict ponts on a well-defined production surface.

The data are subject to two types of errors (Griffin, 1977): 1) errors in measurement that result from differences between the observed technological matrix and the technically correct matrix, and 2) behavioral errors that result because the frictionless long run cost minimization subsumed by the process analysis/statistical reduction approach does not obtain in the short run. Another problem involves determining the size of the experimental region. If it is too small, then the process model tends to generate an "all or nothing" response which can render statistical estimates useless. Over too large a region, the mathematical model may not accurately represent the responses.

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SECONDARY MATERIAL DEMAND AND SUPPLY RESPONSES

by

ROBERT C. ANDERSON

INTRODUCTION

The desirability of either the solid waste user fee or the consumer goods product charge can be evaluated according to several criteria: administrative feasibility, effectiveness, efficiency, equity, legal and political feasibility. Other participants in this conference have addressed the issues of efficiency, equity and administrative feasibility. In this paper I will address the issue of effectiveness with special reference to the consumer goods product charge. The principal analytical tools are a set of econometric models of the ferrous scrap and wastepaper markets, developed over the past few years under grants from the Environmental Protection Agency.

As currently envisioned, the consumer goods product charge would be structured as an excise tax on inputs to the production of consumer goods which ultimately enter the solid waste stream (e.g., beverage containers, newspapers, packaging materials, etc.). Of two principal production inputs, virgin materials and secondary materials, only the virgin inputs would be subject to the product charge. This would create a change in the relative prices of virgin and secondary materials and, theoretically, produce shifts in resource use patterns and in resource recovery as the effects filter through the economic system.

In order to project accurately the probable impacts of regulatory actions such as the product charge, one must have a detailed knowledge of the market parameters of interest, the demand and supply elasticities for both virgin and secondary materials. This paper is principally devoted to a discussion of our most recent empirical work in this area. Quantitative assessments of the likely impacts of the product charge based upon estimates presented here are left to others.

As noted the econometric models presented here are extensions of the ferrous scrap and wastepaper demand and supply models developed for EPA in a previous study.[1] Three major modifications have been made to the earlier published models. (1) The original ferrous scrap model was based on the years 1962-1972; this model has been updated to include data through October 1977. The wastepaper model was previously estimated over the period January 1962-December 1974 and has been extended to August 1977. This additional period is especially interesting because of the large price changes in both materials which occurred between 1973 and 1975. (2) The earlier ELI models for wastepaper and ferrous scrap were two equation demand and supply systems. Additional equations are added here to represent market behavior more accurately. The ferrous scrap model now contains supply, demand, export demand, and mill inventory equations. (3) In the wastepaper model, the supply of ferrous scrap was initially hypothesized to be a function of price, activity in the prompt producing sectors (automobile production), scrap exports, lagged prices and a trend variable. Some alterations were made to this equation to improve the fit (exclusion of the trend variable) and to accommodate the export equation (scrap exports were added to the left-hand side of the equation). A few other minor changes in the demand equation for ferrous scrap and the wastepaper supply and demand equations are discussed below.

THE WASTEPAPER MODEL

The wastepaper model, as it now stands, is composed of four equations.

Demand: (1)

$$Q_t^D = a_0 + a_1 p_t + a_2 X_{(t)} + a_3 X_{3(t)} + a_4 X_{4(t)} + U_t$$

Supply: (2)

$$Q_t^s = b_0 + b_1 p_t + b_2 X_{1(t-1)} + b_3 X_{2(t-2)} + b_4 P_{(t-j)} + E_t$$

Inventory: (3)

$$I_t = c_0 + c_1 I_{(t-1)} + c_2 Q_t^D + c_3 \Delta Q_t^D + c_4 P_{(t-1)} + V_t$$

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[1] Environmental Law Institute, Impact of the Federal Tax Code on Resource Recovery. Prepared for the Environmental Protection Agency. Washington, D.C.: PB-264 886, 1976. Also, Anderson, R. C. and Spiegelman, R. D., "Tax Policy and Secondary Material Use." Journal of Environmental Economics and Management (JEEM), 4 (1977): 68-82.

Identity: (4)

$$Q_t^s = Q_t^D + (I_t - I_{(t-1)})$$

Where:

Q_t^D	is the consumption of wastepaper in thousands of tons
Q_t^s	is the purchases of wastepaper in thousands of tons
P_t	is the wholesale price index of wastepaper deflated by the wholesale price index for all commodities (1967 = 199) and multiplied by 1000
X_1	is the Federal Reserve Board Index of paperboard container production (1967 = 100) multiplied by 10
X_2	is the Federal Reserve Board Index of converted paper product production (1967 = 100) multiplied by 10
X_3	is the output of construction paper and board in thousands of tons
X_4	is the output of combination paperboard in thousands of tons
W_t	is the wholesale price index for market wood pulp (all grades) deflated by the wholesale price index for all commodities and multiplied by 1000
$P_{(t-j)}$	is an Almon lag over wastepaper prices lagged one to four months
I_t	is inventories of wastepaper held by major consuming mills at the beginning of the month in 1000's of tons

Estimates of the structural coefficients (the a's, b's and c's) of equations (1) through (3) were obtained by two stage least squares. All equations were corrected for first order serial correlation. The final estimated equations are reported below. T-ratios appear in parenthesis under the respective variable.[2]

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[2] The properties of T-ratios and other test statistics in simultaneous equation systems have not been fully developed. The T-ratios should be interpreted as guidelines to the significance of the variables.

Demand: (5)

$$Q_t^D = 41.9 - \underset{(-4.3)}{0.13}P_t - \underset{(-1.0)}{0.03}W_t + \underset{(4.8)}{0.37}X_{3t} + \underset{(15.9)}{1.51}X_{4t}$$

Supply: (6)

$$Q_t^s = 51.9 + \underset{(11.4)}{0.36}P_t + \underset{(1.5)}{0.08}X_{1(t-1)} + \underset{(4.8)}{0.25}X_{2(t-2)} - \underset{(0.09)}{0.004}P_{(t-j)}$$

$$\rho = .45$$

Inventory: (7)

$$I_t = -39.6 + \underset{(21.8)}{0.95}I_{(t-1)} + \underset{(0.7)}{0.04}Q_t^D - \underset{(-1.2)}{0.08}\,\Delta Q_t^D + \underset{(1.7)}{0.03}P_{(t-j)}$$

$$\rho = -0.05$$

All the variables but one have the proper sign as suggested by economic theory. Demand responds negatively to price. The estimated elasticity of demand, evaluated at the means, is 0.19. Consumption of wastepaper is a positive function of activity in construction paper and board, two sectors of the paper industry that are large users of wastepaper. While one would expect the price of woodpulp to have a positive impact on wastepaper demand, the estimates presented here show a negative sign, although the variable is not significant.

The supply of wastepaper is positively related to price, with an estimated short-run elasticity of 0.5. The negative sign for lagged prices is also expected since the level of prices in past time periods provides a good index to the extent of depletion to the reservoir of available scrap. No medium term elasticity is reported because the lagged price variable is insignificant. The generation of prompt industrial scrap, represented by the lagged values for paper board container and converted paper production, acts to increase the supply of scrap as indicated by the positive sign for these variables.

Comparison of the current wastepaper estimates with estimates from the earlier ELI models, reproduced in Table 1, must be done with some care. In order to take advantage of the publication of a more consistent series, the price variable for wastepaper was changed in the updated model. The previous model used a wholesale price index for wastepaper that was based on two different base years, 1957-1959 and 1967 = 100, the new series has been weighted to a single base year, 1967 = 100. It does not seem likely, though, that this modification can account for the over twofold increase in the demand elasticity, 0.08 in the first study to .19 in the current work. The same sort of change was made to the woodpulp price index, but cannot be taken as the cause of the negative sign for that variable. The estimates of the supply elasticity are similar in both studies.

TABLE 1. COMPARISON OF ESTIMATED ELASTICITIES FROM PAST AND CURRENT ELI WASTEPAPER MODELS

Elasticity	EPA	Estimate* JEEM	Current
Demand	0.16	0.08	0.19
Gross price	0.13	0.17	0.12**
Supply (short-run)	0.40	0.53	0.50
Supply (medium-run	0.15	0.40	0.50

* Reported elasticities refer to the EPA study cited earlier based on the years 1962-1972, then the results published in JEEM (based on the years 1962-1974).

** Estimates based on the years 1962-1972.

One cause of the difference in the price coefficients of the demand equations may be found in the market convulsions of 1973-75. The beginning of the period was marked by a world wide increase in demand for paper products, as well as most other commodities. This was shortly followed by a more than proportional increase in the demand for wastepaper as non-traditional users entered the market. Mills that normally relied upon woodpulp inputs were buying wastepaper to compensate for a developing shortage of pulp for paper production.

In response to increased demand, the price of wastepaper more than doubled from early 1973 to the first quarter of 1974. The price of woodpulp also rose during this time period. During the period from October 1973 to November 1974 consuming mills increased their inventories of wastepaper, possibly in anticipation of even further price increases. (Time series data for these variables are plotted in Figure 1).

By mid-1974, the commodity boom had begun to slip into the recession period of 1975. As demand for paper products declined, demand for wastepaper inputs fell even more as mills used up accumulated inventories instead of buying in the market. The wholesale price index for wastepaper fell from a

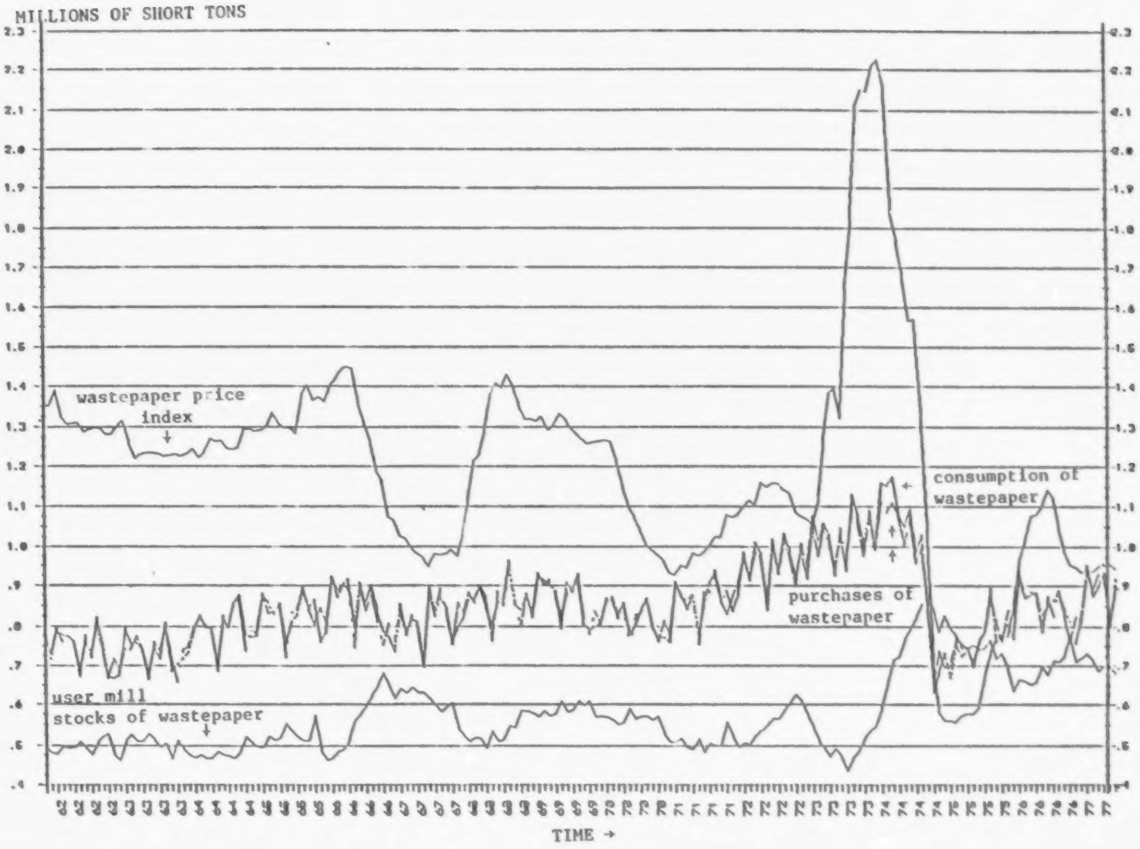

Figure 1. Time series plot of wastepaper data, from January 1962 through August 1977

high of 222.4 in March 1974 to 56.1 in March 1975. The price of woodpulp did not experience such a severe drop. Actually, the higher prices of woodpulp, established during the 1973-74 period, held fairly constant throughout the recession period of 1975. As shown in Figure 2, these price patterns signalled a change in the historical relationship between woodpulp price and the consumption of wastepaper.

More formally, the inability of the wastepaper demand model to capture the substitution effect of woodpulp for wastepaper can be formulated as an error-in-variables problem. It is likely that while posted woodpulp prices remained high in the aftermath of the shortage period, actual prices were somewhat lower due to discounts being given buyers. The wholesale price index for woodpulp would not account for such discounting. The use of this index would generate biased estimates of the woodpulp price coefficient and unreliable elasticity estimates.

To demonstrate the effect of the different price structure for woodpulp on the demand for wastepaper, the demand equation was re-estimated using two woodpulp price variables, one representing prices before 1973 and another representing prices after 1973. It was anticipated that the price of woodpulp prior to 1973 would have a positive sign and the post-1973 price would capture the change in the woodpulp price - wastepaper consumption relationship. The pre-1973 woodpulp price had a marginally significant positive sign and an elasticity of 0.12. The post-1973 price was not significantly different from zero.

The higher price elasticity of demand, although still quite inelastic, can be explained, at least in part, by the large increases and ensuing decreases in the consumption and price of wastepaper. It seems likely that industry decisionmakers behave differently at different points in the business cycle. Mills may be more responsive to prices that are rapidly increasing than to prices that are falling. The fact that the elasticity estimates presented in Table 1 vary depending on the time periods on which the models were estimated lends some credence to this hypothesis.

Although there were major price and therefore demand changes from late 1972 to early 1975, an analysis of the residuals from the demand equation suggests that the estimated equation was able to account for most of the shifts in demand that occurred during this period.

All of the variables in the inventory equation have the proper sign as suggested by the theory outlined earlier, although only the once lagged price ad inventory variables were significant.[3] The extremely small coefficient of adjustment (δ), .05, suggests that inventories are adjusted only a fraction each month towards the desired level. This is understandable

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[3] The specification of the inventory equation is discussed in detail in "Analysis of Scrap Material Supply and Demand." Draft Interior Report No. 2 to the EPA. Prepared by E.L.I., September 1978.

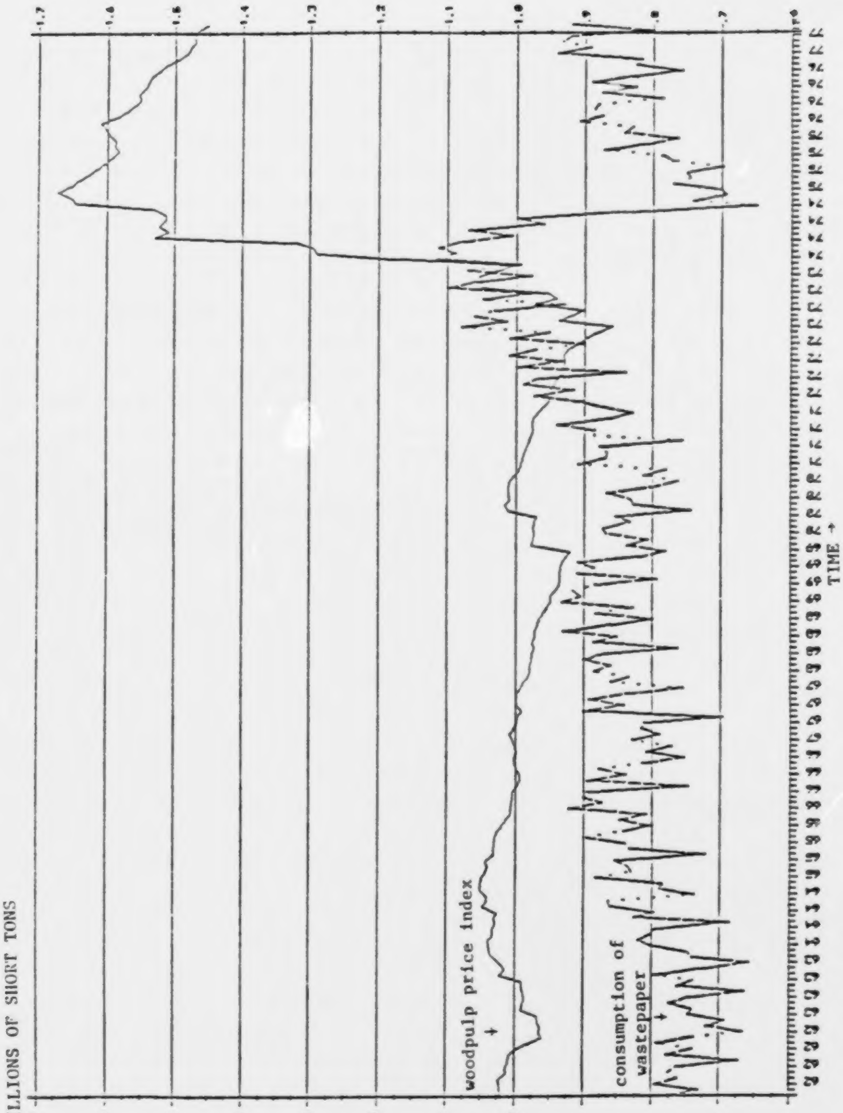

Figure 2. Time series plot of woodpulp price and wastepaper consumption data.

given the variable nature of scrap prices and the high cost of holding wastepaper in storage. Past rates of change in consumption appear to be more important in determining inventory adjustment plans than current consumption. This would be the case if many of the mills that consume wastepaper do not produce strictly to order.

Several different forms of lagged prices were used in the inventory equation and all generated similar results. The once lagged price variable was chosen based on maximum explanatory power of the equation. The fact that stocks of wastepaper are adjusted in response to expected price is not surprising in light of inventory behavior during the 1973-1974 period described above.

THE FERROUS SCRAP MODEL

The four structural equations making up the ferrous scrap model are:

$$Q_t^D = b_0 + b_1 P_t + b_2 X_{1t} + b_3 X_{2(t-j)} \tag{8}$$

$$Q_t^s = a_0 + a_1 P_t + a_2 X_{3t} + a_3 P_{(t-j)} \tag{9}$$

$$Q_t^E = c_0 + c_1 P_t + c_2 X_{4t} \tag{10}$$

$$I_t = d_0 + d_1 I_{(t-1)} + d_2 X_{5t} + d_3 \Delta X_{5t} P_{(t-1)} \tag{11}$$

where:

Q_t^D	is net receipts of ferrous scrap (all grades) in thousands of tons
Q_t^s	is total receipts of ferrous scrap (net receipts plus exports) in thousands of tons
P_t	is the wholesale price index of ferrous scrap (all grades) deflated by the wholesale price index for all commodities (1967 = 100) and multiplied by 1000
X_{1t}	is total U.S. steel production in thousands of tons
X_{2t}	is an Almon lag of the wholesale price index of market pig iron deflated by the wholesale price index for all commodities (1967 = 100) multiplied by 1000, lagged five to eight months
X_{3t}	is the Federal Reserve Board Index of automobile production (1967=100) multiplied by 10

X_{4t}	is an index of total foreign steel production
Q_t^E	is net U.S. exports (exports - imports) of ferrous scrap all grades) in thousands of tons
I_t	is beginning of month stocks of ferrous scrap (all grades) in thousands of tons
X_{5t}	is the U.S. consumption of ferrous scrap in thousands of tons
$P_{(t-j)}$	is an Almon lag on the ferrous scrap wholesale price index lagged one to four months

The structural coefficients of equations 8-11 were estimated by two-stage least squares and corrected for first order serial correlation. The estimated equations were:

$$Q_t^D = 353.58 - \underset{(-1.8)}{0.90}P_t + \underset{(9.5)}{0.26}X_{2t} + \underset{(1.2)}{0.65}X_{3(t-j)} \tag{12}$$

$$\rho = .53$$

$$Q_t^s = 350.85 + \underset{(18.9)}{2.16}P_t + \underset{(11.9)}{0.67}X_{1t} - \underset{(.24)}{0.04}P_{(t-j)} \tag{13}$$

$$\rho = .77$$

$$Q_t^E = 402.49 - \underset{(-0.6)}{0.05}P_t + \underset{(3.3)}{0.076}X_{4t} \tag{14}$$

$$\rho = .65$$

$$I_t = 270.12 + \underset{(46.4)}{0.96}I_{(t-1)} - \underset{(-0.9)}{0.02}X_{5t} - \underset{(-0.6)}{0.02}\Delta X_{5t} + \underset{(2.2)}{0.13}P_{(t-j)} \tag{15}$$

$$\rho = 0.1$$

The demand for ferrous scrap is negatively related to price although the coefficient is only marginally significant. The elasticity of demand, estimated at the means, is 0.34. The elasticity of scrap demand with respect to total production, 0.92, indicates that demand for ferrous scrap rises almost proportionately with increases in steel production. A one ton increase in the production of steel increases the demand for scrap by .26 tons. The lagged pig iron price has the expected positive sign but is not significantly different from zero.

All of the variables entering the supply equation have the appropriate sign, although lagged scrap prices are not significant. The short-run supply elasticity at the means is 0.71. The production of automobiles, which in the process generates prompt scrap, augments the supply of scrap forthcoming at any given price.

Although the U.S. scrap prices are shown, in the export demand equation, to have an insignificant effect on the foreign demand for U.S. scrap, activity in foreign steel industry is an important determinant of demand. An increase in total foreign steel production has a positive impact on the quantity of scrap exported. There are several possible reasons for the lack of an estimated price effect. (1) It may be that exports are exogenously determined from the rest of the model. If this is the case, scrap exports should appear as an explanatory variable in the supply equation. (2) While foreign consumers may actually respond to the price of U.S. scrap, the price variable used in the equation may not reflect the true U.S. export price for scrap. The price index used in the analysis is highly aggregated and may give more weight to prices in non-exporting cities or grades of scrap that are not normally exported in large quantities. (3) The equation may omit other variables that are important in a foreign scrap consumer's decision to import U.S. scrap. The most obvious example of this is the lack of a variable defining the costs of transporting scrap to the importing country. It seems reasonable that the level of transportation costs would be a significant factor in explaining demand for U.S. scrap. (4) While current prices may not affect current export demand, an expected or lagged price variable may play a more prominent role in determining the level of scrap exports at any given point in time. This same argument applies to the activity variable. More attention must be paid to the specification of the export demand equation before firm conclusions concerning the existence of a price effect can be made.

Initially it was felt that the imposition of export controls during part of the data period may have been one reason for the insignificant price effect in the export demand equation. Export controls on ferrous scrap were imposed by the U.S. Department of Commerce in July 1973 in an attempt to assure domestic consumers adequate supplies of ferrous scrap during a period of unusually strong demand. The first form of export control required all export shipments of over 500 tons to be licensed, beginning with orders accepted after July 1. Regulations for orders of 500 tons or more received after July 1 were not issued until later. All orders of less than 500 tons would be granted licenses. The effect of these control regulations was to reduce the size of individual orders but appears to have little immediate effect on the total amount of exports. In August 1973, scrap exports were actually higher than they had been in July.

In September, the Commerce Department acted on the problem with unlimited small orders and stopped consideration of any small orders received after September 11, although orders over 500 tons which had been received prior to July 1 could still be filled. In addition, Canada and Mexico were allowed to import up to 75,000 tons of U.S. scrap per month.

The licensing system was replaced by a quota system in the first quarter of 1974. The quotas were based on historical export patterns and licenses were granted based on the country to which the scrap was to be exported. The quota was set at 2.1 million tons for each quarter until export controls expired on December 31, 1974.

An attempt was made to estimate the impact of export controls on export demand. A dummy variable was included in the export demand equation that had a value of 0 for the period before and after controls, and a value of 1 for the period August 1973 - December 1974. The coefficient of the dummy variable was insignificant indicating that export controls may have had little impact, perhaps because the demand for exports was already declining by the time controls were imposed.

The inventory equation suggests that the level of stocks held by scrap consuming mills is predominantly a positive function of stocks and a negative function of scrap prices in the previous month. The extremely small coefficient of adjustment ( ), 0.04, indicates that like wastepaper inventories, actual stocks of ferrous scrap adjust slowly to desired levels. During a one-month period stocks are adjusted only 4% of the amount of adjustment required to reach the desired level of inventories. The absence of a strong short-run buffer stock motivation for holding stocks, evidenced by the insignificant consumption and change in consumption variables, may indicate the consuming mills react to longer-run considerations. The positive sign for the lagged price variable seems consistent with a visual analysis of the price and stocks data plotted in Figure 3. For the most part, the level of stocks rises with increases in the ferrous scrap price. Two periods are exceptions to this rule. From early 1972 to late 1973, stocks of scrap at consuming mills fell quite regularly in the face of sharply increasing prices. Mills were depleting inventory levels to hold down the cost of raw materials. This trend was reversed in late 1974. As scrap prices began to fall, mills replenished their inventories. When prices returned to more normal levels, stocks on hand continued to increase above the historical average. Further research is required before the inventory behavior in these two periods can be adequately specified in the model.

Table 2 reports summary statistics of elasticities for this model and our earlier model. The fact that the current model shows the demand and supply of ferrous scrap to be less responsive to price signals (more inelastic) than in the earlier model may be the result of several factors. These will be discussed in turn.

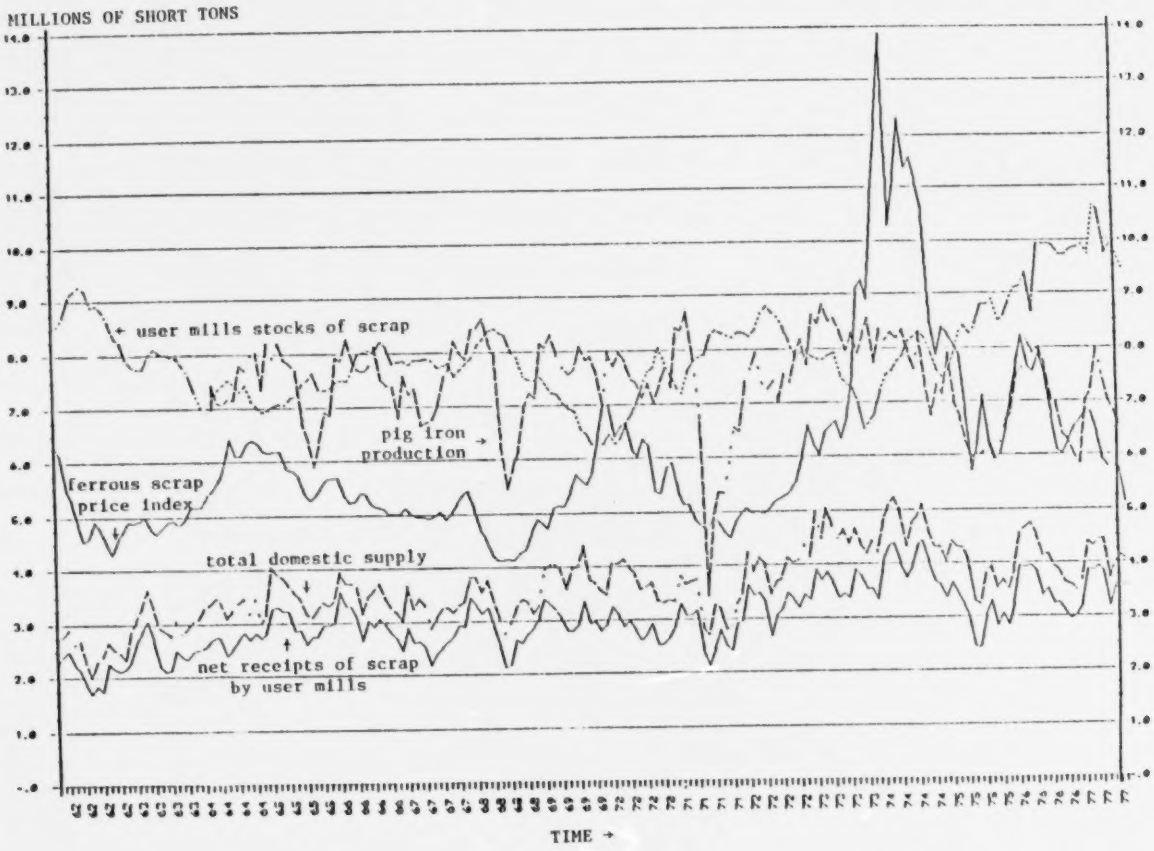

Figure 3. Time series plot of ferrous scrap data, January 1962 through October 1977.

TABLE 2. COMPARISON OF ESTIMATED DEMAND AND SUPPLY ELASTICITIES FOR FERROUS SCRAP

Elasticity	Estimates EPA*	 Current
Demand	0.64*	0.34
Supply:		
Short-run	1.43	0.71
Medium-run	1.12	0.71**

* Environmental Law Institute.

** No significant medium term effect.

(1) Like wastepaper demand, the demand for ferrous scrap inputs increased during the commodity boom of 1973 more than proportionately to the demand for final steel outputs. This was due to a relative shortage of coke for pig iron production. To compensate for the lack of pig iron, mill demand for scrap increased. In response, the price for scrap rose to all-time highs, as shown in Figure 3, between the beginning of 1973 and early 1974. Unlike wastepaper, though, the supply of scrap did not increase significantly in response to the new higher prices. Several structural changes in the market acted in concert to limit scrap supply and create a shortage of ferrous scrap.[4] (a) There was a decrease in the availability of home and prompt scrap. Prompt scrap generators returned scrap back to the originating mills instead of selling scrap to brokers or dealers. In addition, higher yield steel products were being produced, cutting down on home scrap production. (b) A scarcity of gondola cars constrained the movement of scrap to areas with the greatest demand. (c) In anticipation of higher prices and further shortages, mills began to build up inventories above levels required by current consumption needs. The lower estimated elasticity of supply from the current model can, in large part, be ascribed to the shortage conditions described above.

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[4] The Commodity Shortages of 1973-1974: Case Studies. Prepared for the National Commission on Supplies and Shortages. Washington, D.C.: U.S. Government Printing Office, 1976.

(2) The price controls, that were in effect from 1972-1974, may have had some effect on the responsiveness of demand to price. Analysis of the theoretical impact is clouded by the different price control regulations that were enacted during this period. Generally, controls were placed on all unprocessed industrial scrap. Small scrap dealers were exempt from price controls while dealers with over 60 employees were not. In December 1973 a one-time cost pass through was allowed on a dollar-for-dollar basis for both buyers and sellers. Prices were set at the average price during the last quarter of 1973.[5] By early 1974, all ferrous scrap was exempted from price controls. Our attempts to estimate the impacts of price controls on ferrous scrap supply and demand were unsuccessful.

(3) The price indexes used here are highly aggregated, fixed weight averages of the published market prices. These prices may not be accurate representations of the true prices to which scrap consuming mills react. To the extent that they do not reflect the actual market prices, both the demand and the supply elasticities may be understated and biased.

Furthermore, the nature of the prices making up the pig iron price index may provide some insight into the insignificance of the variable in determining demand for scrap. Since the market price for pig iron is a posted price, and then only accounts for a small portion of total pig iron consumed, it may not accurately reflect the relative scarcity or abundance of the input. The impact of the availability of pig iron on the demand for scrap might be better captured by a variable depicting the production of pig iron and not its price. A pig iron production index was included in the scrap demand equation. Although it did not generate entirely satisfactory results, pig iron production was a significant and positive determinant of the demand for scrap.

(4) Finally, the definition of the dependent variables for the supply and demand equations may not be specific enough to display all of the subtle changes that occur in the ferrous scrap markets during periods of rapidly increasing (or decreasing) prices. For example, the average grade of purchased scrap is known to change with changes in the price of scrap.

CONCLUSIONS

This paper demonstrates that econometric models of secondary materials markets yield results which are consistent with known institutional relationships and with economic theory. It is important to recognize the limitations of the econometric approach, however, before directly applying the parameter estimated developed here to policy problems. The estimated demand elasticities are believed to understate seriously the actual long-run parameters of the scrap consumers. For policy purposes it may be reasonable to employ much higher direct price elasticities of demand and infinite cross elasticities.

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[5] This is a highly simplified view of the complex system of price control policies and regulations enacted during 1972-1974. A more detailed outline of the price regulatory events can be found in The Commodity Shortages of 1973-1974: Case Studies.

On the supply side, one important adjustment must be made. If one is interested in the impact of product charges or other similar forms of market intervention on the recovery of post-consumer secondary materials, one must adjust the elasticity estimates. This adjustment is necessitated by the fact

On the supply side, one important adjustment must be made. If one is interested in the impact of product charges or other similar forms of market intervention on the recovery of post-consumer secondary materials, one must adjust the elasticity estimates. This adjustment is necessitated by the fact that the market models are estimated for all scrap (prompt industrial scrap plus post-consumer scrap) as dictated by the manner in which the data are reported. If one assumes that prompt scrap recovery is unaffected by price, the fact that prompt ferrous scrap comprises approximately 50% of total supply would dictate that the reported supply elasticity be doubled. For wastepaper, approximately 40% is prompt, indicating the wastepaper supply elasticity should be increased to 1.67 times its reported value.

SECTION 6

PRICING AND SOLID WASTE MANAGEMENT

"The Seattle Solid Waste Management Experiment: User Charges and Separate Collection of Recyclables" (Bernard H. Booms).

THE SEATTLE SOLID WASTE MANAGEMENT EXPERIMENT:
USER CHARGES AND SEPARATE COLLECTION OF RECYCLABLES

by

BERNARD H. BOOMS

ACKNOWLEDGEMENT

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THE SERVICE AREA - THE SETTING

This section provides a general profile of the Seattle area and describes the current residential solid waste management system operated by the City of Seattle. The purpose of this descriptive material is to familiarize the reader with the setting for the Seattle experiment and to highlight situational factors which could conceivably influence the development and outcomes of the experiment.

Description of the Area

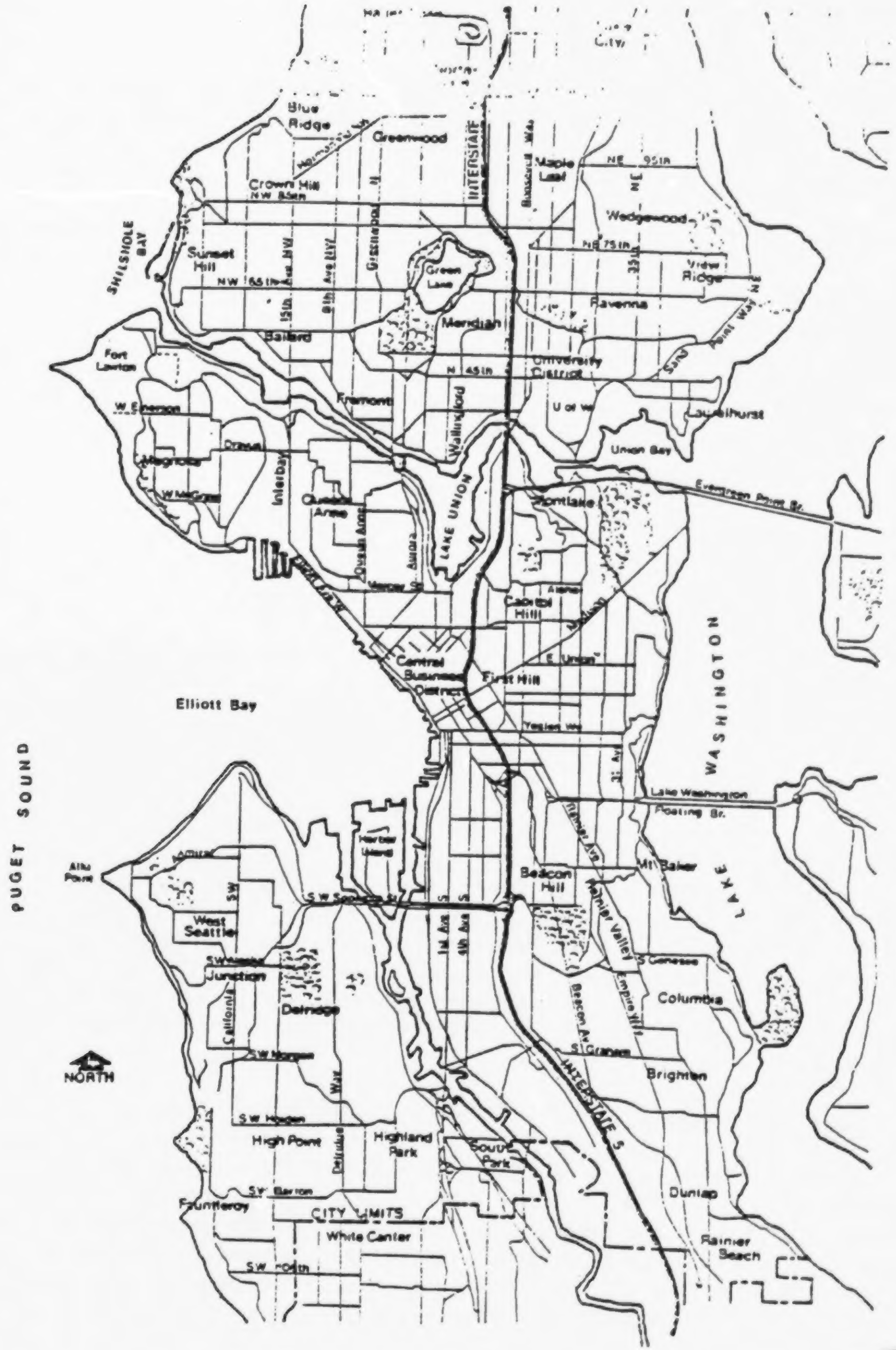
Population and Geography--

The City of Seattle is located in Washington State on the shores of Puget Sound. The current 1978 population is estimated to be 490,000. The boundaries of the city encompass about 88.5 square land miles (91.5 sq. miles of area including lakes and waterways). The area is bounded on two sides by water, with Puget Sound to the west and Lake Washington to the east. An aerial view of the land mass reveals an hourglass shape. (Perhaps because of her "figure" Seattle is called the Queen City!) The city is thus geographically divided into north and south sections with the downtown area at the narrowest part of the hourglass being the usually accepted dividing line between the north and south sections (See Map 1).

Topography--

Seattle was once a city of seven hills, but the marvels of engineering reduced the number to six hills and one regarded bump! Nevertheless, the general terrain is still far from flat with many areas of rolling hills and numerous areas with steep hills. Obviously, the hill

Map 1


City
Blue Ridge
Greenwood
INTERSTATE 5
Maple Leaf
NE 95th
NE
Crown Hill
NW 85th
Wedgewood
SHILSHOLE BAY
NE 75th
35th
View Ridge
Sunset Hill
NW 65th
15th Ave NW
8th Ave NW
Greenwood
Green Lake
Ravenna
Sand Point Way NE
Meridian
Ballard
Fort Lawton
N 45th
University District
Fremont
W Emerson
Wallingford
U of W
Laurelhurst
Dravus
Union Bay
Magnolia
W McGraw
Interbay
LAKE UNION
Evergreen Point Br.
Queen Anne
Queen Anne
Aurora
Montlake
Mercer St
Aloha
Capitol Hill
Madison
E Union
Central Business District
First Hill
Elliott Bay
Yesler Wy
WASHINGTON
PUGET SOUND
31 Ave
Lake Washington Floating Br.
Harbor Island
Rainier Ave
Alki Point
Admiral
SW
Beacon Hill
Mt Baker
LAKE
SW Spokane St
1st Ave S
4th Ave S
West Seattle
Rainier Valley
SW Alaska
Junction
S Genesee
Empire Way
Beacon Av
Columbia
California
Delridge
NORTH
SW Morgan
S Graham
Brighton
Way
INTERSTATE 5
SW Holden
High Point
Delridge
Highland Park
South Park
SW Barton
Dunlap
Fauntleroy
CITY LIMITS
White Center
Rainier Beach
SW 106th

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nature of the area makes the operation of collection vehicles and the collection of solid waste more difficult than in flat areas. This is especially true during the winter months when the ground is occasionally snow or ice covered.

Climate--

The climate is generally mild. Summer daytime temperatures usually reach the upper 60's to middle 70's. Summer days with temperatures over 80 are unusual. Winter daytime temperatures range in the high 30's to 40's. Below freezing readings occur only about 15 days in an average year.

Seattle has a reputation for being rainy. This reputation is based less on absolute amounts (average 36 inches/year) and more on consistency. The Seattle area is often cloud-covered, and rain, when it falls, occurs at a light rate for long periods.

Winds are seldom strong. Normal wind speeds are 3 to 7 miles per hour. Winds are rarely strong enough to blow debris about during the collection process and cause collection difficulties.

Population and Housing Characteristics--

Table 1 depicts population and housing statistics for Seattle and offers comparative statistics in some instances with selected cities over 250,000 population surveyed by R. L. Polk and Company. The comparative statistics were calculated by Polk based on 1975 data.

Population--Seattle has a population mix quite different in several important dimensions from most other cities of similar size. The age distribution of Seattle's population tends to be bimodal to the younger and older ends of the scale. Seattle has become predominately a city of young, single, often highly educated, high income persons, and of retired, older, lower income persons. The degree of Seattle's singleness obviously influences the proportion of households with children, with a higher proportion being childless in comparison to other cities. It appears that national trends of urban population composition are exaggerated in Seattle. The high proportion of young, single or young married persons with high education and income levels in Seattle suggests a great potential interest in and willingness to participate in social experiments. The attitudes found in Seattle can be a strong determinant in the observed outcomes of the experiment, and any attempt to transfer the findings from Seattle to other areas should be done with caution.

Housing--Approximately 65% of the population live in single family housing units. There is a trend for more single people to occupy single family housing. Solid waste collection for the 35% of the population living in multiple family units is most often carried on using large collector containers with resultant economy of collection. But approximately 5% of the structures in the city have 5 or more housing units, so that large scale collector systems are not extensively used. Despite a high proportion of single persons in the population, Seattle continues to retain a relatively low population density.

TABLE 1. SUMMARY OF POPULATION AND HOUSING DATA IN SEATTLE AND OTHER CITIES OVER 250,000

	Seattle	Other cities over 250,000, 1975 data
Population	490,000	--
% White	85%	--
% Non-White	15%	--
% Black	9%	--
% Other	6%	--
Households	203,237	--
Average persons/HH	2.4	--
% One person HH	35%	Average 26% Range 20% -- 31%
% HH with children	24%	Average 38% Range 30% -- 40%
% Retired heads of HH	27%	Average 20% Range 16% -- 26%
Housing units	216,058	--
% Single family units	65%	--
% Multiple family units	35%	--

Source: 1977 Polk Data and City of Seattle.

Collection and Disposal

Solid waste operations for the City of Seattle are run as a utility. Utility status means that the solid waste operation must "stand on its own bottom," i.e., operate without subsidy from the City's general fund. Fees are charged for the service and these fees must cover all costs of operation.

For solid waste management purposes the city is divided into two service areas. These areas coincide with the north and south geographic sections of the city described earlier.

The city operates a transfer station in each service area. These transfer stations are the points where the two contracted commercial haulers deliver their collections. The city then transports the solid waste from the transfer station to the city-operated disposal sites. The transfer stations are also open for residents (and for non-residents at a fee) for individual dropoff of solid waste.

The Solid Waste Utility controls and manages only residential solid waste. Disposal of commercial solid waste is left to the private sector, without city involvement. One major commercial firm dominates the commercial collection and disposal business. This firm operates a marine transfer station in the downtown area. This station is used to transfer commercial solid waste to a barge. The waste is then hauled out of the county area and disposed of on a private landfill site north of Seattle.

Map 2 shows the boundaries of the service areas and the location of the transfer stations.

The city has recently passed an ordinance that could require that all material be disposed of at city-operated landfills and run through the city-operated transfer stations.

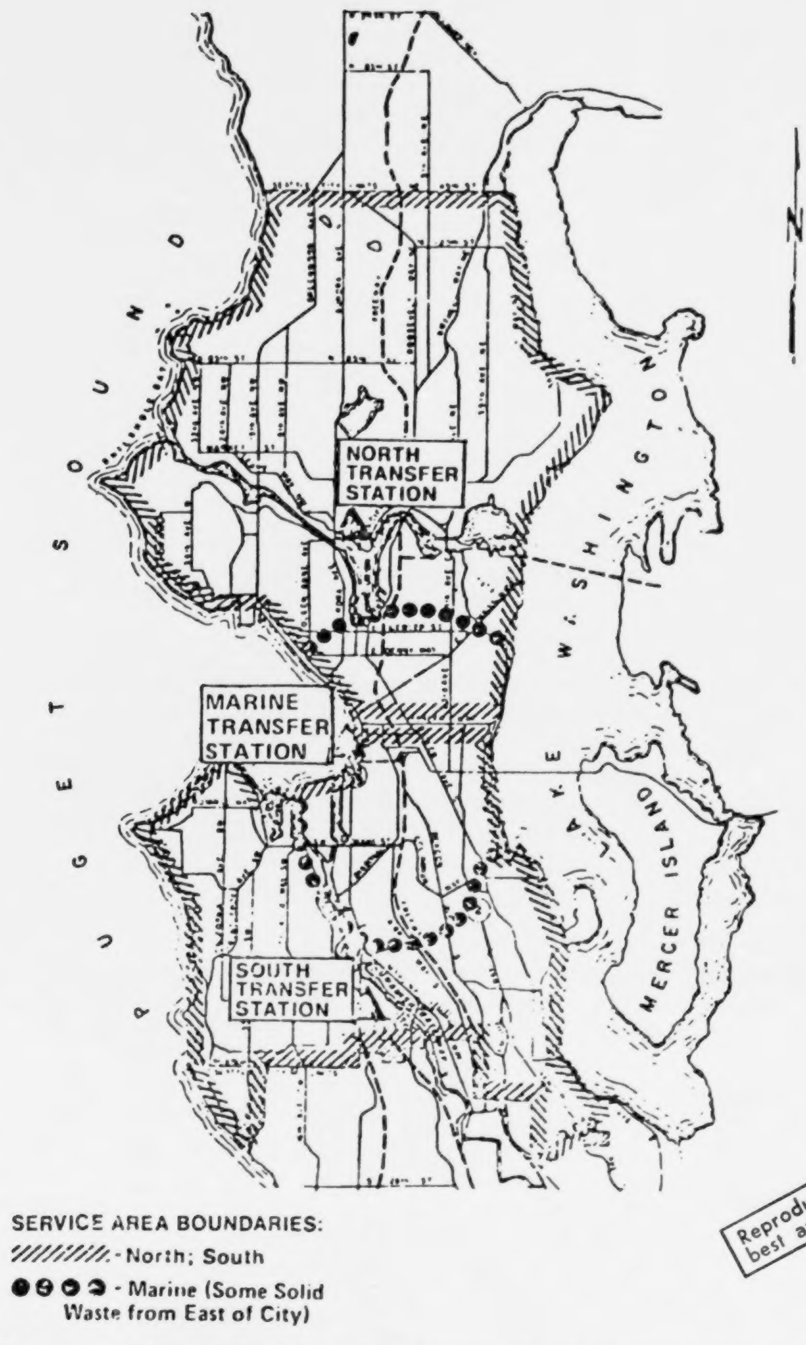
Charges for the collection and disposal of residential solid waste are collected on a flat fee basis by the city. Charges per single family household are currently $5.20 a month for an allowable limit of 4 conventional garbage cans plus two ordinance units (boxes or bags of non-putrescible substances) per can (total allowable ordinance units, 8).

Collection—

The collection service is operated on a contract basis by the city with the two service areas being separate bidding areas. Award rules for service contracts prohibit any single contractor from being awarded the contract for both areas.

Collection frequency is once a week. Backyard pick-up is provided. Though curbside placement is purely voluntary, it is estimated that from 15% to 20% of the households do set their cans at curbside on collection day. Setting cans at curbside is one way residents can obtain special favors from collection crews, like accepting occasional oversized or overweight items.

Map 2


PUGET SOUND
LAKE WASHINGTON
MERCER ISLAND
N
NORTH TRANSFER STATION
MARINE TRANSFER STATION
SOUTH TRANSFER STATION
SERVICE AREA BOUNDARIES:
▨ - North; South
● - Marine (Some Solid Waste from East of City)

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Source: City of Seattle, Departments of Engineering and Lighting, Seattle's Solid Waste ... An Untapped Resource, May 1974.

Approximately 30% of households are on alleys; in these areas, collection is via the alley. Alley collection usually involves shorter distances for the collection crews to walk in picking up the solid waste. A recent survey showed that 52% of the housing units locate their refuse containers only in the backyard, while the remaining 48% utilized a combination of backyard, curb or alley locations for their containers.

The current distribution of can usage per household within the City is estimated to be:

Zero cans	1%
1 can	20%
2 cans	60%
3 cans	15%
4 cans	4%

A recent survey of container usage and volume of refuse indicated that the average number of units per stop was 1.9 cans and 0.1 ordinance units. The average weight of material per stop was 53 lbs., ranging from 40 to 69 lbs.

Disposal—

Two disposal sites are currently leased and operated by the Solid Waste Utility. The two landfill sites are both outside of the city limits. The close-in Midway site is nearly up to grade and is limited to non-putrescible wastes. The Kent-Highlands site is estimated to have only three years of capacity remaining at current rates of solid waste generation. The city pays a disposal royalty of 65 cents/ton for the use of the landfills.

Waste Flow

Approximately 550,000 tons of solid waste are collected each year in Seattle. This flow is composed of approximately 218,200 tons/year of residential waste and 331,800 tons/year of commercial waste.

A study of percent composition by weight of solid waste in the area that includes Seattle estimated the following percentage breakdown by waste type.

TABLE 2. PERCENTAGE COMPOSITION BY WEIGHT OF COLLECTED SOLID WASTE IN COUNTY AREA THAT INCLUDES SEATTLE

Waste type	1971 data residential		1973 data industrial/commercial	
Paper	41%		22%	
Newspaper		15%		0
Cardboard		6%		7%
Mixed Paper		20%		15%
Plastic	5%		1%	
Ferrous Metals	6%		3%	
Aluminum	1%		1%	
Glass	7%		15%	
Garbage (putrescible)	13%		5%	
Other combustibles	13%		34%	
Wood		1%		19%
Garden		10%		0
Other		2%		15%
Inerts	14%		19%	

Source: Market Analyses of Recovered Materials and Energy from Solid Waste, CH2M Hill Study, 1977.

A follow-up study using these percentage estimates attempted to determine the proportions of paper, ferrous metal, aluminum and glass currently not entering the collected solid waste stream and being recycled instead. Table 3 illustrates the estimated level of recycling activity prior to the beginning of the Seattle experiment and compares these levels with "maximum possible" recovery rates published by EPA.[1]

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[1] Maximum possible effort estimates are based on use of all presently accepted technologies and favorable market prices for recyclables.

TABLE 3. ESTIMATES OF RECYCLED MATERIAL IN SEATTLE AND EPA MAXIMUM EFFORT ESTIMATES

Waste type (tons)	(1) total recycled/ collected material	(2) recycled material	(3) collected material	(4) percentage recycled/total	(5) EPA/s percent "maximum effort"
Paper	225,791	63,333	162,458	28	46
Newsprint	53,922	21,192	32,730	39.3	55
Cardboard	60,268	23,950	36,318	39.7	55
Mixed paper	111,601	18,191	93,410	16.3	35
Plastic	14,228		14,228		
Ferrous metals	30,973	7,927	23,046	25.5	63
Aluminum	9,820	4,320	5,500	43.9	46
Glass	88,929	23,885	65,044	26.8	50
Garbage	44,956		44,956		
Other combustibles	141,178		141,178		
Wood	65,224		65,224		
Garden	21,820		21,820		
Other	54,134		54,134		
Inerts	93,590		93,590		
Totals	649,465	99,465	550,000	15.3	

Source: City of Seattle.

It is clear that Seattle is an active recycling area. Approximately 15 percent of all material is being recycled. This compares with a recycling rate of 7 percent on the national level.

Twenty-eight percent of the paper, 44 percent of the aluminum, 27 percent of the glass and 26 percent of the ferrous metal are being recycled. This high recycling rate may be explained by the attitudes and characteristics of the population which were described earlier. A large number of groups and individuals are involved in recycling operations throughout the city. One estimate places the number of recycling operations (church and school paper drives, etc.) around 120. At least 18 recycling locations pay cash for one or more recyclable materials.

Figures 1 and 2 give an indication of the monthly and daily averages of solid waste material flow from the Seattle area.

BACKGROUND

In this section the factors leading up to the experiment will be outlined, and the nature of the citizen and governmental initiative described.

Factors Leading to the Experiment

Citizen Concerns—

During 1976 the City of Seattle renegotiated the refuse collection contracts. As a part of this process, the City Council held public hearings. Citizen input at these hearings revealed that some individuals were not satisfied with a flat fee charge. These vocal individuals argued that the flat fee was unequitable because the fee was fixed regardless of the amount of waste generated (up to four containers). Thus the driving factor behind the variable rate portion of the experiment seems to be a concern with equity.

Landfill Capacity--

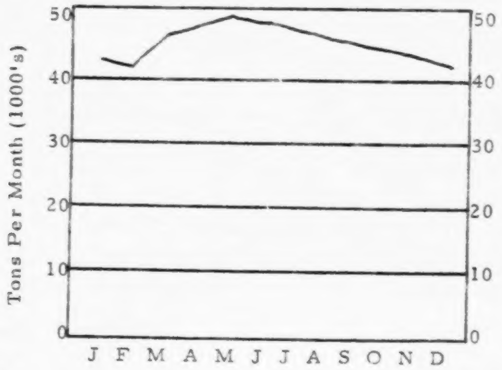
For a number of years the City has realized that at current rates of solid waste generation it will soon exhaust its present landfill capacity. This concern has led to the study of a number of alternative disposal methods, including using the waste for fuel or for making ammonia. Source separation and recycling have also been discussed as ways of extending the life of the landfill. Landfill capacity and imminent decision on locating another landfill or using other technology were also factors leading to the experiment.

Thrust of the Experiment

Several broad areas of concern could be said to be factors behind the experiment.

	Average	
	T/Mo.	Av. T/Day
January	41,818	1,349
February	41,150	1,470
March	45,770	1,476
April	48,086	1,603
May	49,908	1,610
June	49,217	1,641
July	48,621	1,568
August	47,549	1,534
September	46,036	1,535
October	45,256	1,460
November	43,057	1,435
December	42,568	1,373
Total (TPY)	549,036	
Monthly Avg.	45,753	

NOTE: Data include the estimated Marine Transfer Facility quantities of 220,800 T//Yr., or 18,400 T./Mo., assumed constant year-to-year and month-to-month.



Source: City of Seattle

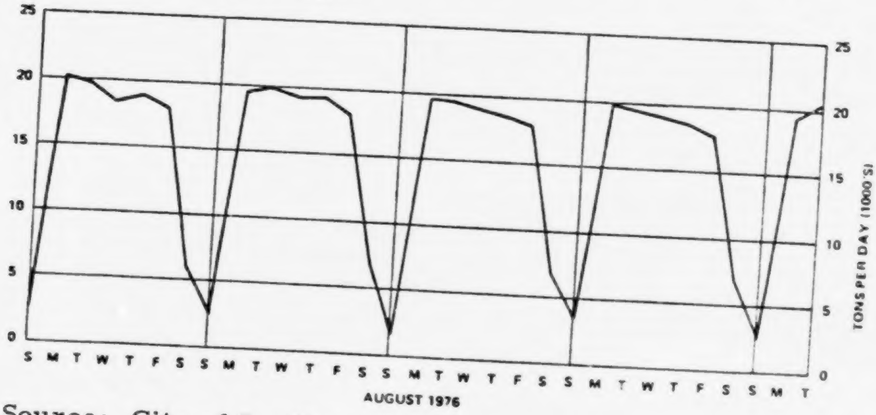
Figure 1. Five-year annual average of solid waste.

Date	Day	NTS + STS	STS Cars	* MTF	Total	%
1	Su	171	110	0	281	19
2	Mo	1,116	132	767	2,015	134
3	Tu	1,094	140	767	2,001	133
4	We	990	96	767	1,853	124
5	Th	1,021	102	767	1,890	126
6	Fr	951	89	767	1,807	121
7	Sa	157	118	383	658	44
8	Su	122	133	0	254	17
9	Mo	1,099	101	767	1,967	131
10	Tu	1,120	106	767	1,993	133
11	We	1,075	109	767	1,951	130
12	Th	1,074	108	767	1,949	130
13	Fr	964	83	767	1,814	121
14	Sa	229	110	383	722	48
15	Su	116	62	0	178	12
16	Mo	1,122	89	767	1,978	132
17	Tu	1,072	101	767	1,940	129
18	We	1,040	106	767	1,913	128
19	Th	1,003	77	767	1,847	123
20	Fr	956	92	767	1,815	121
21	Sa	229	179	383	791	53
22	Su	212	112	0	324	22
23	Mo	1,123	114	767	2,004	134
24	Tu	1,105	104	767	1,976	132
25	We	1,046	92	767	1,904	127
26	Th	993	86	767	1,846	123
27	Fr	947	82	767	1,796	120
28	Sa	220	123	383	726	48
29	Su	178	88	0	266	18
30	Mo	1,105	107	767	1,979	132
31	Tu	1,149	115	767	2,031	135
		Daily Average	=	1,499 tpd		

* Based on an estimated rate of receipt of 18,400 tons per month, received at an assumed equal daily rate 5-1/2 days per week.

Source: City of Seattle.

Panel A. Solid waste received at North (NTS) and South Transfer Stations (STS), and the Marine Transfer Facility (MTF), in tons per day.



Source: City of Seattle.

Panel B. Seattle solid waste handled daily, August 1976

Figure 2

Equity--

It has already been suggested that equity among households seems to be the most often stated factor motivating the experiment. This concern is readily understandable by the average citizen and has broad appeal.

Ironically, if the service level of the collection system, i.e., the frequency and location of pick-up, account for a large proportion of costs and these costs are not appreciably influenced by the amount of material collected, then a flat fee charge may be more equitable than a variable charge based on the quantity of refuse! (It should be noted that the fee structure can vary according to service level. Some cities are currently using such a rate structure.)

Efficiency--

Concerns relating to the allocation of resources focus on social costs and benefits being equal to individual costs and benefits and the true costs and benefits being borne by the individual making the resource allocation decisions. In this way the consumer can correctly compare the consequences of alternative resource allocation decisions. The variable rate is one way of trying to ensure that the costs of solid waste generation are borne by the generator, thus facilitating informed decision making by the consumer in trading off between more or less waste generation activities. However, little mention is made about efficiency in discussions of the experiment.

Implementation--

Another area of concern that could relate to the experiment is implementation questions. The experiment is viewed, in part, as a method for identifying implementation problems and for trying alternative implementation schemes. The experiment is an opportunity to learn -- on a trial basis -- how to operate alternative solid waste systems. City government is especially interested in discovering problems without having to risk the possibility of a big failure (see below). So information potentially useful to implementation concerns is also a partial basis for the experiment.

Initiative in the Experiment

It is important to realize that the initiative for the experiment started with the citizens and was picked up by the City Council. The Council, not the City Utility (city department) initiated the call for an experiment. The city department has been reactive to the idea of an experiment, rather than proactive.

The environment in local government may help to explain why the initiative lies where it does. As a result, error is terror for city bureaucrats. The constituents are close at hand to complain if things go wrong and there are often individuals willing to turn mistakes into political advantage. Most often the facts of life for bureaucrats in this setting are such that if you do the same old thing and something goes wrong, it is an act of God, but, if you try something new and it goes wrong, it is your fault! Therefore, organizational resistance to experiment and change is increased.

It is important to understand the environment in which the experiment is being conducted when considering the experiment and thinking about suggestions for modification to the experiment.

THE EXPERIMENT

In this section the objectives and design of the Seattle Solid Waste Experiment are discussed. The experiment was designed under contract with a consulting engineering firm. The program is currently being managed by the City's Solid Waste Utility. The actual running of the experiment and the evaluation have been contracted out by the City to private firms. These firms are responsible for the regular collection of solid waste under a variable rate structure, a recycling program based on home collection, and evaluation -- as well as design — of the experiment.

The experiment consists essentially of three test treatments in the mangement of solid waste. The treatments are:

Variable Can Rate

In selected areas of the City, residents are charged for refuse collection and disposal on the basis of the number of refuse containers they use. Household participation in the test areas is on a voluntary basis.

Source Separation with Separate Truck Collection - Recycling

In selected areas, residents have the opportunity to voluntarily separate recyclables from their refuse for separate collection on a schedule different from the regular solid waste pick-up schedule. The resident is asked to separate waste into three recyclable categories: glass, metals, and newspaper.

Variable Rate Plus Source Separation

In selected areas, both of the above described treatments are being tried simultaneously. The variable rate applies only to containers used for refuse, and not to containers used for the recyclable materials. Again, participation in both treatments is voluntary, and the resident can volunteer for one or both of the elements of the treatment.

An evaluation of these various treatments is being conducted as a part of the Seattle Solid Waste Experiment.

The Objectives of the Experiment--

There are several written statements outlining the objectives or goals of the experiment. The main objectives are as follows:

> To test the feasibility of a variable can rate structure and determine its impact on refuse generation and collection.
>
> To test the viability and economic feasibility of separate collection of household sorted recyclable materials.

To test the impact of separate collection of household sorted recyclables on refuse generation and collection.

To test the impact of a variable can rate structure on household participation rates for separate collection of sorted recyclables.

The research design developed for the City under contract was prepared to meet these stated objectives. The research design contains little discussion or analytical framework relating to possible hypothesized impacts (both wanted and unwanted) of the various experimental treatments. Without the benefit of such a model or analysis it is difficult to determine a methodology for evaluating the experiment and, in fact, to design the experiment and identify data collection needs.

The Research Design

The research design was constrained by several factors. First, was a concern and a requirement that the experiment be as self-supporting as possible, and that in no case should the experiment result in more than $250,000 of utility funds being dedicated to the project, or result in more than $55,000 of revenue loss to the utility. In addition, the experiment had to meet all tests of legality.

The test of legality raised the most difficult complication in research design. The City Attorney rendered an opinion that variable rates exceeding existing standard rates would be illegal under State law requiring that all utility customers of the same class be charged at the same rate. Thus, the possibilities for designing a rate structure that would reward residents who generate little waste and penalize those who generate large amounts of waste, while at the same time generating the revenue needed to cover the total costs of the service, were greatly limited. As a result, a proposed variable rate that had considerable differentiation between numbers of containers had to be abandoned. The variable rate is discussed in detail below.

Three Treatments--

Three treatments are involved in the experiment: variable rates, source separation and separate collection of recyclables, and a combination of these two treatments. Participation in all cases is voluntary. A part of the experiment is to determine the response of the residents to the various treatments, given various promotional and educational efforts.

Treatment Areas--

Thirty areas in the City were identified for inclusion in the experiment. In addition, five control areas similar to the test areas were designated for inclusion in the study so as to provide baseline data which allow for measurement of seasonal and weather factors that influence solid waste collection.

The thirty treatment areas represent regular collection routes or combinations of regular collection routes.

Each of the three treatments is tried in 10 of the 30 test areas. Each set of 10 test areas was picked so as to be representative of the City as a whole. The areas were selected on the basis of income, housing density, topography, and location within the City -- with income levels being the dominant selection factor. For each treatment, there are two low income areas, two high income areas, and six middle income areas.

The treatment or test areas are not contiguous, and are spread throughout the City.

Test areas 1 through 10 are the variable rate areas; areas 11 through 20 receive a combination treatment of variables rates and recycling, and areas 21 through 30 are the recycling only areas (Maps detailing these areas are available from the City of Seattle.).

Variable Rate--

The collection and disposal of solid waste is being conducted by the regular contractors. The level of service is identified by special stickers on the containers. Cans without stickers are not collected. This system was chosen over route books because it was believed to be more efficient, and also because the high proportion of alley pick-up in the City limits the suitability of the address-based route book system.

The variable rate treatment areas are being monitored by five City employees hired throught the CETA program. (The CETA contribution to the experiment amounts to approximately $75,000.) The monitors follow the collection crews, recording numbers of containers collected and the time required for the various components of the collection process. The monitors also make general observations about the collection process and the experiment. The monitors are responsible for attaching the stickers to the containers and for making sure the sticker system is kept operational.

The billing for the variable rate areas is conducted through the regular City billing system.

Early in the design phase of the experiment there was much discussion concerning how to determine the "appropriate" variable rate structure. Ideally, the rates should reflect the marginal costs of collection and disposal. In the absence of any data on marginal costs (on a container basis) the discussion focused on the requirement to generate revenues needed to cover the cost of the experiment and on guesses as to what rate spread would provide the desired incentives to residents. The following rate structure was proposed.

Number of Containers	Rate
Zero cans	$1.00
1 can	4.60
2 cans	5.60
3 cans	7.00
4 cans	8.50

When the City Attorney was asked to review this structure he suggested that it would be illegal on the basis that several of the proposed rates exceeded existing rates for residents outside of the test area receiving similar service.

Two alternate rate structures were considered (see below), but these were judged inappropriate either because they generated insufficient revenue or because they did not appear to provide a large enough incentive for residents to modify their behavior.

Alternative Rate Structures Considered

No. of Cans	Rate	No. of Cans	Rate
Zero	$1.00	Zero	$1.00
1	2.80	1	4.00
2	4.00	2	4.95
3 or 4	5.20	3 or 4	5.20

Rate Structure Finally Adopted

No. of Cans	Rate
Zero	$1.00
1	4.00
2, 3 or 4	5.20

This rate was judged to minimize revenue loss and to provide a "reasonable" incentive to switch from two can to one can service. (It was felt few residents would be willing to move to a zero can service level.) It was noted in the discussion that thir rate structure has the drawback of not providing a rate break between the 3 and 4 can users. It remains to be seen if the experimental rate structure provides incentives for the big waste generators to reduce waste output.

It is important to make clear the fact that the one can service does not include collection of ordinance units. What doesn't fit in the one can is not collected, and the resident must dispose of any extra himself or store it for collection at the time of the next pick-up. No provision is made for occasional increases in the amount of solid waste generated, e.g., from yard cuttings or special events such as the holiday seasons. This fact may have cut down on the number of residents willing to adopt the one can service level. Note also that in treatment areas where both the variable rate and recycling tests are in operation, containers for the recyclable material are not counted in the variable rate.

Generally, the discussion about what rate structure to adopt was based on guesses, hunches, common sense, with the greatest emphasis being on revenue needs. Words like "ideal," "appropriate," and "reasonable" were used to describe various alternative rates, without the words themselves being given precise meaning. There is a need for cost information on which to base such rate making decisions.

Source Separation and Separate Collection of Recyclables--

The sorting and recycling part of the experiment is being conducted under contract by a private recycler -- Seattle Recycling, Inc. The research design specified certain requirements that the recycling contractor had to satisfy in his operation of the experiment. These requirements seem to be aimed at ensuring that the technology and procedures used in the recycling process would represent efficient equipment and processes for large scale operations. In this way experimental operating experience would be indicative of operating results that might be obtained in a citywide program. The aim of the experiment is to simulate a citywide program. To further this end -- publicity requirements, processing requirements and requirements for the marketing of collected recyclables are specified in the research design.

To assist the household in the storing of source separated material, each participating household is provided with two cloth mesh bags (potato bags) for holding metal and glass and one plastic bag for newspapers -- at the time of each collection. The bags are cleaned and recycled back to the households.

Combination of Variable Rate and Recycling--

The combination of the two treatments is carried on in 10 test areas. The contractors each conduct their separate portions of the experiment. No modifications to the two treatments or special arrangements are used in the combination test areas.

Current Evaluation Design--

Considerable mention is made in the research design of the data to be collected. The data monitoring is summarized in Figure 3, taken directly from the Final Research Design.

The current evaluation effort appears to be heavily focused on the "time and motion" aspects of the collection and recycling process.

Experiment Modification--

The managers of the experiment have indicated from the conception of the experiment that the program is and will continue to be open to modification. Thus, the possibility exists to make additions or changes in both the research design and the evaluation procedures. As early results become available, modifications will begin to be considered.

SOME EARLY RESULTS AND OBSERVATIONS

Some results are available based on the first month of operation of the Seattle experiment.

Response and Participation Rates

Figure 4 and Tables 4 through 7 summarize the response rates and actual participation rates for the various treatments and test areas.

Variable Rate--

The participation in the variable (one can rate) rate test averaged 12%. There was no difference in the participation rate between those areas wit and without separate collection of recyclables. This finding is contrary to the expected outcome. One might assume that collection of recyclables would make movement to the one can level of service feasible for most households.

The 12% participation rate was obtained using only a mail solicitation. In addition, media coverage described the variable rate program.

Approximately 30 households chose the zero rate. The households have been given composting information and are being monitored by the city health department.

Income levels did not seem to systematically influence the observed participation rates among the various test areas.

Recycling—

A total of 58% of the households responded favorably to being involved in the recycling experiment. A higher proportion of households in the combination treatment areas (61%) expressed a willingness to be involved than in the recycling-only treatment areas (55%).

Variable Rate Program

Monitoring in the variable rate areas (and control areas as well) will include recording of the following information both prior to implementation and once every two months thereafter:

- Frequency distributions for the number of refuse containers and ordinance units per stop;
- Average quantity of refuse per stop;
- Frequency Distribution for the collection time per stop;
- Average Travel time between stops;
- Total stops serviced per day;
- Total tons collected per crew per day;
- Total time to service pilot and control areas;
- Miscellaneous travel times and distances (yard and route, route to landfill, landfill to yard, etc.);
- Number of trips to landfill;
- Unavoidable delays and breakdowns;
- Scheduled breaks.

Source Separation and Separate Truck Collection

Monitoring in the pilot areas performing source separation of recyclables is more extensive than in the variable rate only areas.

Prior to implementation, monitoring tasks are identical to those summarized in the last section on the variable can rate test. Once source separation begins, it will be necessary to monitor not only ongoing refuse collection activities but also the source separate collection as well.

Below is a list of the data required for evaluation of the source separate collection of glass, metal, and newspaper.

- Addresses of homes participating by setting out recyclables (percent participation);
- Identification of recyclables set our (newspaper, glass, metal);
- Average quantity of recyclables by type per stop;
- Frequency distribution of time per stop for recyclables collection;
- Average travel time between stops;
- Total time for separate truck to service pilot area;
- Miscellaneous; times and distances (yard to route, route to yeard, etc.);
- Unavoidable delays and breakdowns;
- Scheduled breaks.

With this data, the source separate collection method can be evaluated for performance and cost. A sample form for collection of this data follows. Naturally, the control areas will not be involved nor monitored for source separation.

At the yard area, monitoring will again be performed to identify the manpower required and time associated with unloading, processing and storage of the glass, metals, and newspaper collected. This data will allow cost trade-offs to be made, and other sorting/storage techniques to be evaluated.

Monitoring will be relatively simple consisting basically of recording times and labor requirements for the various processing and sorting operations previously described. Typical activities to be timed include:

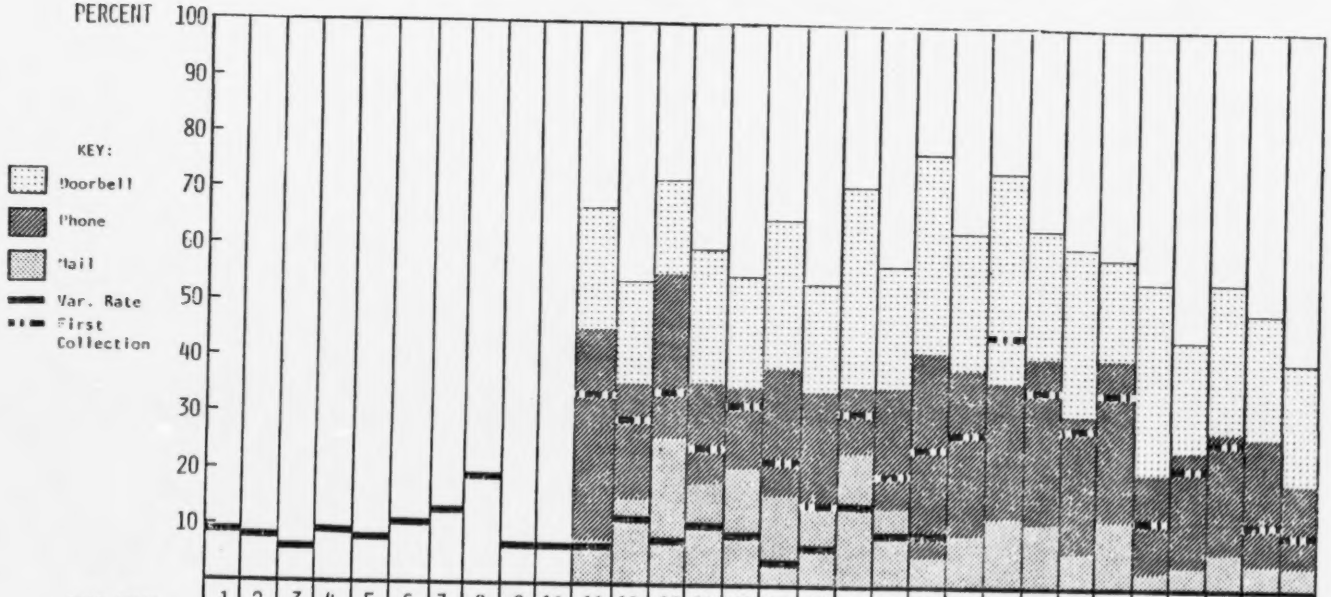
- Unhook trailer;
- Paper unload from pick-up to roll-off bin;
- Position and dump metal bin, oversee convey, magnet, crushing system;
- Position, unload glass bin.
- Sort glass.

Variable Can Rate Plus Source Separation

The monitoring requirements for the combined variable can and source separation pilot program are virtually identical to those for source separation above. Again, pilot areas and control areas will be selected.

Source: Final Research Design: Seattle Variable Rate Source Separation Pilot Programs, City of Seattle, 1978.

Figure 3. Monitoring Design



TEST AREAS	1	2 H	3	4	5	6 H	7 L	8	9 L	10	11 H	12	13	14	15 H	16	17 L	18	19	20 L	21	22 H	23 H	24	25	26 L	27	28	29	30 L
TREATMENT	VARIABLE RATE ONLY										VARIABLE RATE AND RECYCLING										RECYCLING ONLY									
DATA																														
Doorbell	-	-	-	-	-	-	-	-	-	-	101	118	81	175	95	77	92	119	138	142	122	146	81	122	109	181	119	135	125	114
Phone	-	-	-	-	-	-	-	-	-	-	160	122	135	121	54	62	85	33	112	146	132	81	94	109	168	100	127	136	122	85
Mail	-	-	-	-	-	-	-	-	-	-	39	95	121	122	91	46	72	76	82	24	48	64	40	20	92	14	19	31	23	17
Variable rate	83	62	48	55	71	45	30	17	73	65	66	61	64	71	48	54	68	23	70	47	-	-	-	-	-	-	-	-	-	-
Total HHH	786	489	328	469	539	451	361	203	522	457	448	643	480	713	445	291	475	327	596	409	436	399	346	423	658	537	595	546	564	522
SES	M	H	M	M	M	H	L	M	L	M	H	M	M	M	H	M	L	M	M	L	M	H	H	M	M	L	M	M	M	L
1st collection	-	-	-	-	-	-	-	-	-	-	154	184	170	179	142	63	67	98	133	90	137	184	124	123	220	75	125	156	75	63

Source: Seattle Recycling, Inc. and City of Seattle.

Figure 4. Percent response Seattle experiment.

TABLE 4. PARTICIPATION SUMMARY VARIABLE RATE TREATMENT

Areas	Treatment		#HH total on map	%
1 - 10	Variable only	543	4605	12%
11 - 20	Combination	572	4827	12%
Total		1115	9432	12%

Source: City of Seattle

TABLE 5. RESPONSE SUMMARY RECYCLING TREATMENT

Areas	Treatment	Mail	Phone	Doorbell	Total # HH responding	Total # HH on maps	% response
11 - 20	Combo	768	1030	1138	2936	4827	61%
21 - 30	Recycle only	368	1164	1254	2786	5076	55%
Total		1136	2194	2392	5722	9903	58%

Source: Seattle Recycling, Inc.

TABLE 6. FOLLOW-THROUGH SUMMARY (1ST COLLECTION) RECYCLING TREATMENT

Areas	Treatment	Total HH collected	Total # HH responding	% follow-through
11 - 20	Combo	1280	2936	44%
21 - 30	Recycle only	1272	2786	46%
Total		2552	5722	45%

Source: Seattle Recycling, Inc.

TABLE 7. ACTUAL PARTICIPATION SUMMARY (1ST COLLECTION) RECYCLING TREATMENT

Areas	Treatment	Total HH collected	Total # HH on maps	% participation
11 - 20	Combo	1280	4827	27%
21 - 30	Recycle only	1272	5076	25%
Total		2552	9903	26%

Source: Seattle Recycling, Inc.

The follow-through percentage, i.e., the proportion of those households who said they would participate -- and actually did, overall was 45%. In other words, over half of the households who said they would participate did not put out recyclable materials during the first collection period. Time will tell if this "drop out" rate reflects actual rejection of the program or just forgetfulness in putting out materials for collection.

The recycle-only treatment areas had a higher follow-through rate (46%) than the combination treatment areas (44%), thus offsetting the greater initial response rates for the combination treatment areas.

Actual participation rates for all recycling areas averaged out to 26%. The combination treatment areas averaged a 27% participation rate, whereas the recycle-only treatment areas had a 25% response rate. How much of the 2% point difference can be attributed to incentives created by the existence of a one can rate is difficult to judge. In any case, 2% points do not seem like a very large difference between the two treatments.

In the case of recycling treatments, the income levels in the test areas did seem to have a systematic influence on participation. High income areas tended to have higher participation rates and lower income areas lower rates. (This finding parallels results from previous studies.) The highest participation rate for an area was 46% (test area 22, a high income area); the lowest rate was 12% (test area 30, a low income area).

Material Collected and Revenues

Trash--

Information on the amount of non-recycled material is being recorded, but is not yet analyzed.

Recycled Material--

The data on the amount of recycled material collected are presented in Table 8.

Revenues--

Information on materials collected, market prices for the materials and the resultant revenues are given in Table 9.

Other Data

Time and motion type information and costs data are being recorded, but these statistics are not yet available.

Some Observations

Several implementation difficulties have been encountered during the early operations of the experiment.

TABLE 8. AMOUNT OF RECYCLABLE MATERIAL COLLECTED (1ST COLLECTION) IN POUNDS
(June 19, 1978 -- July 14, 1978)

Route	Metal	Glass	Newspaper	Total	Percent participation	Average
11	677	3,494	4,503	8,674	34%	26%
12	885	4,065	3,854	8,804	29%	
13	861	3,042	4,139	8,042	35%	
14	929	3,409	3,926	8,264	25%	
15	600	3,359	3,332	6,291	32%	
16	353	1,200	1,068	2,621	22%	
17	255	1,345	581	2,181	14%	
18	250	1,650	2,380	4,280	30%	
19	640	2,480	2,010	5,130	22%	
20	374	1,889	2,877	5,140	22%	
21	623	2,310	3,100	6,033	28%	25%
22	805	3,816	6,799	11,420	46%	
23	458	2,880	4,180	7,518	36%	
24	567	1,826	3,448	5,841	29%	
25	1,521	5,367	6,289	13,177	33%	
26	310	1,250	2,036	3,596	14%	
27	620	1,760	4,391	6,771	21%	
28	585	3,060	3,610	7,255	28%	
29	260	1,422	1,950	3,632	13%	
30	280	1,325	1,006	2,611	10%	

Source: Seattle Recycling, Inc.

TABLE 9. AMOUNT OF MATERIAL COLLECTED, MARKET PRICES AND REVENUES
(1ST COLLECTION) (June 19, 1978 -- July 14, 1978)

Material	Amount Collected in Tons Unless Indicated Market	Amount collected	Revenues
Paper	$36.00/ton	33	$ 1,188
Glass (cullet)	20.00/ton	21	420
Tin/steel	60.00/long ton	4 long tons	240
Aluminum	.22/lb.	2331 lbs.	513
Beer bottles	.60/case	496 cases	298
		Total	$ 2,651

Source: Seattle Recycling, Inc.

Variable Rate—

The main problem encountered with implementing the variable rate has been the use of stickers for differentiating service levels. Trouble first arose when residents objected to the City monitors placing the stickers on the cans.

Several phone calls were received from residents reporting strangers walking around their yards and garbage cans. Some householders have removed the stickers.

In addition, the different colored stickers have faded so that it is difficult to tell the colors apart. The problem is further complicated by the fact that the stickers do not adhere well to some cans. Some effort will have to be made to improve sticker design and technology.

Recycling—

The recycled materials are collected at curbside. A significant number of scavenging incidents have been reported. Efforts are being made to record the extent of this theft problem.

CONCLUSION

The Seattle solid waste management experiment involves the test of a variable user charge for residential refuse service and separate collection of household sorted recyclables. The Seattle program is probably the most extensive residential refuse experiment conducted to date in the United States. It is hoped that the experiment will shed light on the economic feasibility of, and the impact of these proposed innovations, and at the same time provide insights into important implementation questions related to the possible adoption of these suggested innovations.

The Seattle experiment deserves close watching by all those concerned with the study or management of urban refuse systems. The results from the experiment presented here are only preliminary. As of this writing the experiment is still on-going.

SECTION 7

RESEARCH DIRECTIONS

"Research Activities in EPA" (Oscar W. Albrecht).

"Solid Waste Collection/Disposal Economic Research Strategies" (G.S. Tolley, V.S. Hastings).

RESEARCH ACTIVITIES IN EPA

by

OSCAR W. ALBRECHT

INTRODUCTION

I have the privilege of discussing an area that is probably less controversial than some of the areas we've been discussing up to now. The papers have all been interesting and have generated some lively discussion. My assignment is to discuss the research programs of the U.S. Environmental Protection Agency (EPA). I will briefly mention the research and activities of the major offices, and then discuss in a little more detail the research conducted by the Office of Research and Development, and particularly at the Cincinnati Laboratory which is sponsoring this workshop.

RESEARCH BY OFFICES, EXCLUDING THE OFFICE OF RESEARCH AND DEVELOPMENT

The U.S. Environmental Protection Agency (EPA) was established as an independent agency in the executive branch of the federal government, effective December 2, 1970. Many of EPA's activities are enforcement-oriented, but the Agency is involved in numerous research activities throughout the various offices, divisions, and branches of the organization.

The EPA is directed by an Administrator, presently Douglas M. Costle, and reporting to him are various offices headed by assistant administrators. Within these offices are various divisions and branches which conduct research; for example, the Office of Planning and Management has an economic analysis division which evaluates impacts of Agency programs and policies. These impacts include potential plant closings, effects on employment, prices, and Gross National Product (GNP). Estimates of abatement costs and cost/benefit analyses are made for selected industries, principally those pertaining to air and water regulations. The Office of Planning and Management (OPM) frequently performs the impact analyses when program offices do not have sufficient capability or resources to conduct such analyses on their own. The OPM also performs the impact analyses on selected industries where more than one regulation is involved. The investigations by the Office of Planning and Management do not preclude similar research by the various program offices within their own areas of responsibility.

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The Office of Water and Hazardous Material performs economic analyses and prepares inflationary impact statements to support regulations developed by the Office of Water Planning and Standards. The Office also performs cost/benefit analyses, develops and analyzes alternative control options and prepares issue papers describing the costs, risks, benefits, legal, and other aspects of alternative control options.

The Office of Solid Waste (OSW) within the Office of Water and Hazardous Materials has three divisions, each doing research related to their own particular areas of concern. The three divisions in the OSW are: the Hazardous Waste Management Division (HWMD), the Systems Management Division (SMD), and the Resource Recovery Division (RRD). The HWMD conducts economic and policy analyses related to the handling and disposal of industrial and hazardous wastes. It is at present involved in developing criteria and procedures for implementing the regulations mandated under Subtitle C of the Resource Conservation and Recovery Act (RCRA) of 1976. The HWMD is also conducting economic impact analyses of the proposed hazardous waste management regulations for selected industries.

The SMD in OSW has responsibility for a national program to improve the collection, processing, storing, and disposal of municipal and other nonhazardous solid waste. Its major areas of responsibility are providing technical assistance to cities in improving the efficiency and safety of solid waste management, developing a better understanding of the solid waste disposal to land practices, and demonstrating system management plans.

The RRD within OSW performs studies related to the recovery of energy and materials from solid waste. It is also responsible for implementation of a national program to reduce the generation of solid waste. A major focus of RRD has been on large scale resource recovery demonstration projects. The Division has also studied the use of incentives to stimulate demand for seconday materials and waste reduction. Other economic studies by RRD include estimates of consumer demand elasticities for selected products, product charges for solid waste, study of the demand and supply for secondary fiber in the U.S. paper board industry, and the economics of waste oil recovery.

Other offices which conduct economic research include the Office of Air and Water Management which has an Environmental Analysis Division; and the Office of Toxic Substances which has a Benefits and Field Studies Division. Without giving further detail on these, in the remaining time I would like to discuss research by the Office of Research and Development.

RESEARCH CONDUCTED BY OFFICE OF RESEARCH AND DEVELOPMENT

The Office of Research and Development (ORD) is responsible for the national research program for control of all forms of pollution. The ORD's funtions are Agency-wide in satisfying the research and development needs of the Agency's operating programs, and it is responsible for conduct of integrated research within the Agency. Within ORD are four main offices;

these are: the Office of Monitoring and Technical Support; the Office of Energy, Minerals, and Industry; the Office of Air, Land, and Water Use; and the Office of Health and Ecological Effects.

The Office of Monitoring and Technical Support, as the name suggests, is engaged primarily in activities related to monitoring and enforcement. The Office of Energy, Minerals, and Industry (EMI) has responsibility for assessment of environmental and socio-economic impacts resulting from energy and mineral resource extraction, processing, and utilization.

The Office of Air, Land, and Water Use (ALWU) is responsible for assessment of the environmental and socio-economic impacts of land, water, and air pollution control and management activities. This office is also the focal point within ORD for providing liaison with the Office of Water and Hazardous Materials and the Office of Air and Waste Management (which are outside the ORD organization). Within the Office of ALWU is a Waste Management Division which has responsibility for assessment of the environmental and socio-economic impacts of methods to control and manage the discharge of wastes from municipal, recreational and other domestic sources. There is also the Agriculture and Non-Point Sources Management Division within the ALWU, which assesses the environmental and socio-economic impacts of alternative control methods for pollution from agriculture and other non-point sources.

The ORD organization also includes the research laboratories at seven locations over the country. These are at Cincinnati, Ohio; Research Triangle Park, North Carolina; Athens, Georgia; Corvallis, Oregon; Duluth, Minnesota; Naragansett, Rhode Island; and Gulf Breeze, Florida.

Before discussing the research at Cincinnati laboratory, let me briefly mention the other two offices within the ORD. The Office of Health and Ecological Effects (OHEE) has a criteria development and special studies division which is developing economic models and methodologies for conducting socio-economic assessments relating to the benefits of pollution control on an individual and broad program basis. The Office of Toxic Substances has a benefits and field studies division which conducts benefit-cost analyses on the impacts of cancellations or suspensions and the emergency use of pesticides.

RESEARCH CONDUCTED BY MERL, CINCINNATI

Research activities at Cincinnati, by the Municipal Environmental Research Laboratory (MERL), are directed at three principal areas of concern: solid and hazardous waste, wastewater treatment, and water supply.

The Solid and Hazardous Waste Research Division (SHWRD) within the MERL, which is sponsoring this workshop, has to an increasing degree been directing its research to meet the program needs of the OSW which is responding to the RCRA legislation. In our disposal branch, considerable effort is being expended on waste characterization in order to learn more about pollutant transport, including movement through soils by leachates and gases, in order to develop more effective treatment and control methods. The problems associated with co-disposal of municipal, industrial and hazardous waste are also areas investigated and economic and environmental effects of the disposal alternatives are being analyzed.

Waste characterization is also an area of concern for the processing branch because of the implications for resource recovery systems. Our current projects in the area of resource recovery include research on technologies associated with waste-as-fuels, preprocessing techniques for recovery of various fractions from the solid waste stream, and the design of resource recovery systems. Some of our research characterized as economic is more appropriately described as operations research, but it is mentioned here mainly because it does not involve technological hardware.

The first few years after formation of the EPA, several research projects involved studies on the collection, storing, and disposal activities of municipal solid waste. The feasibility of wet systems for collection and transport of residential refuse was investigated, as well as the potential for wage incentives to increase the efficiency of solid waste collection and disposal. Institutional arrangements for regional and solid waste management were studied, and sample and test procedures developed for materials recovered from municipal solid waste. Management systems for hospital and institutional solid waste were examined in detail. A survey was made of housewives' knowledge and attitudes towards solid waste and resource recovery; there was also a study on citizens' attitudes toward disposal of hazardous waste. The manner in which federal government procurement policies and practices affected solid waste recycling was also studied.

On the issue of externalities, we funded a study to measure the external effects of solid waste management. This study, by the Institute of Policy Analysis (IPA), used regression analysis to determine the effects on property values. Using several landfill operations in Los Angeles County (California), it was found that proximity to and view of a sanitary landfill did not significantly affect surrounding property values. This study pointed out, however, that additional work should be done on the specification and exercising of the model as there was inadequate information on the relationship between property values and the non-environmental variables.

In the recent past, there was considerable concern over the abandoned automobile problem. We suported a study to determine the extent of the problem and to evaluate strategies for dealing with it. One suggested strategy was a mandatory deposit fee, refundable upon certification of proper disposal. A case study approach to analyzing the salvage industry was also conducted. This study showed that many salvage firms are family owned, and that salvage firms tended to vary widely in the extent of their operations and capital investments. We also supported a study of the beverage container problem by Research Triangle Institute. The results suggested that government intervention could not be justified solely on the basis of a misallocation of resource inputs. And that to justify government intervention solely on the basis of energy savings would ignore the utility that consumers derive from the convenience of nonrefillable containers.

An important component of the solid waste stream is the combustible portion. This component has been of increasing interest recently because of the concern over diminishing energy sources and high consumption. A study by the International Research and Technology for EPA estimated the magnitude of combustible solid waste; in a subsequent study they developed an input-output model for predicting the quantity and composition of the municipal solid waste. Additional efforts are currently underway to update the estimates using EPA's SEAS model and forecasts of economic expenditure patterns.

Wastepaper is the most important component in municipal solid waste in that it comprises about 35 percent of the total residential and commercial solid waste. Several EPA sponsored studies have investigated this component. A study by Resource Planning Institute, using a pro forma income analysis approach, investigated the potential role of incentives for increasing recycling. It suggested that high subsidies would be needed to obtain a significant increase in recyclng of wastepaper.

Another area of concern has been the issue or allegation of descriminaton in regulated transportation rates, particularly rail freight, and its affect on the recycling of secondary materials. Two studies funded by the EPA arrived at somewhat different conclusions. The Resource Planning Institute study, funded by our office, concluded that on a chemical-equivalent basis ferrous scrap moved at a lower rate than the virgin material while the Moshman Associates study sponsored by the OSW arrived at somewhat opposite results. These differences resulted from variations in the manner in which the data were used, and varying opinions on the appropriate chemical formulae and points of substitution between secondary and competing virgin materials. A shortcoming of these studies, particularly the Moshman study, was the short-run time perspective in which the issues were addressed. At present, we are supporting work at the University of Cincinnati on demand modeling which we hope will ultimately shed further light on this issue.

Another area of concern is the discarded passenger tire disposal problem. Although some discarded tires are recycled as door mats, highway crash barriers, artificial reefs, and the like, these uses constitute only a small solution to the overall scrap tire disposal problem. One recent study, initiated by our office, investigated the net benefits derived from using ground scrap rubber from tires as an additive to asphalt roadways. These potential benefits are currently undergoing further study with actual field tests on several highways. Another study just being implemented will investigate the state-of-the-art, trends, and impediments to various utilizations of the discarded tires.

Resource conservation and recycling have been and continue to be proclaimed as desirable goals which this Nation ought to pursue. A study by the Environmental Law Institute addressed the question as to whether market prices determine resource conservation and recycling in a socially optimal fashion. While the study provided no quantitative estimates of the benefits of conservation, it pointed out that numerous external forces act to create divergencies between the socially optimal prices and the prevailing prices in the market for natural resources. These forces, which act in varying directions and with varying intensities over time, are difficult to measure. Moreover, from an intergenerational viewpoint, a method for determining the socially optimal prices has yet to be devised.

One of the external forces affecting recycling is taxes. The Institute found that elimination of subsidies to extractors through the federal tax code could cause an upward shift of at least 1 percent in the virgin material supply curve for paper; for steel, 2 percent; and copper 5 percent. If taxes were equalized between secondary and virgin materials, considering the supply and demand elasticities, the percentage increases in recycling were estimated as 0.63 percent for wastepaper; 0.42 percent for scrap steel; 0.35 percent for copper; and 1.00 percent for aluminum.

The Environmental Law Institute also conducted a study on the feasibility of using scrap futures markets for encouraging the use of secondary materials. They concluded that futures trading for ferrous scrap and wastepaper was technically feasible, and could result in net gains to society by reducing uncertainty and stabilizing prices and incomes of suppliers and users of secondary materials. Successful operation of such markets however, would depend upon adequate participation by the private sector. A participating role by the government was argued because of the public good aspect of the information generated by the market.

CURRENT RESEARCH AT MERL (SHWRD), CINCINNATI, OHIO

In addition to the projects just mentioned, several new projects have been initiated recently in response to provisions of the Resource Conservation and Recovery Act. The National Academy of Science is establishing for us priorities for government supported research in the area of resource recovery. This study will establish priorities for recovery of both materials and energy from solid waste, taking into consideration the lack of incentives in the private sector to do the needed research, and the net benefits expected to be gained by society.

Another study will investigate the impediments to successful operation of resource recovery facilities. Substantial research efforts in the past have been directed at the technological "know-how" of facilities and techniques for recovering materials from municipal solid waste, but yet the overall recycling rate achieved to date is disappointedly low. This study will investigate in particular how initial plant design and expectations compared with the actual market experiences once the facilities became operational.

In response to the recent legislation (RCRA), we have initiated several new studies dealing with hazardous waste. One study will determine the cost-effectiveness of various treatment and disposal alternatives and the relevance of the various options to management of hazardous waste in the municipal waste streams. Another study will evaluate existing federal programs for risk management, with particular emphasis on the methodologies used by different government agencies in assessing risk, and their applicability to risk assessment for management of hazardous waste.

We are continuing to have an interest in issues related to efficient management of solid waste. Several early studies investigated the theoretical basis for pricing solid waste management and you have just heard the report on the five case studies of user charges conducted for us by Mathtech (the Contractor for this study). Several other studies related to pricing have been mentioned. A list of the past research on pricing and related research was included in the bibliography mailed to each of the participants. The substance of these reports generally emphasize the difficulties encountered in acquiring adequate and meaningful data and indicate the need for further research before any conclusions can be reached. We are, of course, interested in your recommendations for further research in this area.

CONCLUSION

I hope this discussion has given you a general overview of the research activities by the EPA. You have, no doubt, noted that my discussion was mainly on economic research -- the list of research projects in the technological area would be much longer. As stated earlier, the EPA's total research effort is not confined to the ORD, but is spread out among various offices of the Agency. Since the ORD is separate from the enforcement-oriented program offices, perceptions of research needs frequently differ as the research laboratories are inclined towards a longer-run view of research programs. Maintaining an effective degree of continuity in these research projects is sometimes difficult.

Another problem is the coordination of research within the Agency. Up to now, the research efforts in the area of solid waste have been minimal when compared with those for air and water pollution. I think we all agree that the issues on solid waste we've been discussing are important and research support and funding are needed if they are to be resolved. You can help in this effort by articulating these needs whenever you have the opportunity to do so.

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SOLID WASTE COLLECTION/DISPOSAL ECONOMIC RESEARCH STRATEGIES

by

G. S. TOLLEY
V. S. HASTINGS

A question of major concern in municipal solid waste management deals with the rising costs of solid waste collection/disposal. Can there be a payoff in holding down these costs in ways that take into account economic considerations of more than a strictly engineering or technical nature in providing solid waste management services? The rising costs are largely associated with rising input costs, particularly labor, the real cost of which continues to rise, and rising waste volumes. Concerns associated with rising volumes include environmental degradation and increased use of scarce land resources. These concerns are all worth economic investigation if costs can be significantly reduced by economic approaches that would increase net social benefits from solid waste collection/disposal. This paper addresses the subject of research strategies related to the use of incremental user charges as an economic approach for this purpose. Cost-side and then demand-side strategies are discussed, and finally a list of research questions that waste managers might ask is offered.

COST-SIDE STRATEGIES

It is a basic economic proposition that net social benefits are maximized when services are charged for at the marginal cost of providing the services. Under existing methods of financing solid waste services, usually flat user charges or general fund financing, there are no charges related to the amount or to the marginal cost of collection/disposal. This tends to lead to overuse of services in terms of quantity, to the point where costs exceed benefits. However, this does not mean that all charges for solid waste collection/disposal services should be based on amounts collected/disposed. Some services provided are not waste quantity related. Charges for these services should be based on their marginal costs.

This point is worth emphasizing not only because it can make a considerable difference, but because there has been confusion on this point. For example, Ernst (1975) assumed that a choice must be made between either a flat charge or a quantity charge. He related all costs to quantity. This led him to attribute certain empirical findings to scale factors related to population size, whereas in fact more plausible and reasonable explanations were possible based on true cost relationships. Ernst's cost relationships, for example, would result in no costs for traveling a route or going to the back door to look when no wastes were collected. Costs are associated with these actions regardless of quantities collected. Ernst's conclusions concerning the efficacy of marginal cost pricing as a general proposition are thus cast in doubt, even though his conclusions concerning strictly quantity-based incremental charges (for example, his conclusion that incremental charges would not cover costs) are probably correct.

These considerations lead to the research strategy proposition that, for properly setting marginal cost prices, different services associated with solid waste collection/disposal must be identified and their costs determined. In addition to amounts collected, these services include customer services, frequency of collection services, location of collection services, and kind of waste services.

Customer Services

Certain costs are associated strictly with adding a customer. These include billing and adding a stop to the route. This means that part of the total charge should be a flat charge. As an example in another field, electric utilities now often estimate and sometimes include a specific customer charge in their billing, based on billing costs and amortization of customer hookup costs. This avoids the erroneous inference from declining block charge structures that there is a scale factor involved in the cost of electricity to a customer. Declining block charges can be replaced with two marginal cost pricing components that actually apply marginal customer cost and marginal electricity cost components. A summer cottage customer would then be given a true picture of his hookup service costs, and could decide whether to take service based on these costs. He would not impose costs on the system greater than the value of the service to him. In the solid waste field, a customer two miles off the normal route could decide whether he was willing to pay the additional customer service cost to him. Even more to the point, no customer's use of the service in terms of quantities offered for collection would be distorted by an erroneous inclusion of a customer cost in the incremental quantity charge, nor would the solid waste collection agency have the problem of marginal cost prices not covering costs.

Other Services

Other important services include frequency of collection, location of collection such as curb or backdoor, and kinds of waste collected. There may be more, such as service on Mondays as opposed to other days of the week, and quieter service. Each of these other services would have a cost function separate from the quantity of service cost function. The frequency of collection cost function would depend on the cost of traveling the route an additional time per base unit of time, such as per week, the back-door service on distances to back door and time costs for labor and route travel time extension, and the kind of waste on the salvage or special disposal costs of particular kinds of waste. Service on Mondays, if Monday service were in heavy demand for disposing of weekend collected yard wastes, for example, would involve costs for peaking on a Monday (equipment for that day's collection alone). A demand for particularly quiet service on a particular route would involve the added cost of providing equipment and training personnel for quieter service.

The literature has indicated that greater frequency of service (Quon 1965) and backdoor service (Wertz 1976) lead to greater volumes for collection/disposal. However, while these interrelationships are important, they do not affect the basic cost functions for the different services. Thus, the cost functions can be estimated independently of what these relationships might be.

Interrelationships Affecting Costs

Switching to quantity based charges would involve additional customer costs due to the need for measurement of quantitites of various services and of quantity billing. There may also be added littering costs associated with quantity-based charges. Furthermore, switching from general fund financing would involve a cost due to loss of income tax advantages. (Such financing is federal income tax free, whereas individually borne user charges are not.) These considerations lead to the need for a benefit-cost assessment to determine if there would in fact be net advantages in switching to marginal cost pricing for the services.

Cost Variation

Basic cost functions will vary from place to place. In some areas, least cost disposal may be land disposal at close-in low price per acre sites, in other areas the opposite. In some areas, back doors may be close to the street, in others far removed from the street. In some areas, housing may be high density, others low density, leading to different costs for route coverage. Some areas may be more susceptible to littering with incremental quantity charges imposed than others, possibly depending on socioeconomic characteristics. Because of these various differences, any general study of the efficacy of marginal cost user charges must consider the possible ranges in variations of conditions and associated least costs for providing various services.

DEMAND-SIDE STRATEGIES

To estimate whether the potential gains from marginal cost pricing are substantial and if such pricing is worthwhile, various demand curves for services must be estimated. However, estimation has been limited by a lack of sufficient data. Application of marginal cost pricing or any form of incremental pricing that would generate the needed data has been limited. Given this situation, a possible approach for at least partial estimation of demand curves is one based on estimating the cost of alternatives to community collection/disposal services.

Cost of Production Approach

Volumes of wastes collected and associated waste management services can only be substantially decreased if there are lower cost alternatives to waste generation, to community collection, and to the associated services such as frequency of service and location of service. The shape of demand functions for the various collection/disposal services depends on these alternatives and their costs to users. These alternatives include sink disposals, carrying wastes to curb, storing wastes over a longer period, finding alternative collectors for certain wastes and possibly storing those particular wastes longer (e.g., paper to Boy Scouts), and changing consumption patterns to generate less wastes (e.g., use of returnable bottles). Lower cost alternatives to individuals, but not necessarily to society, may also include littering and on-site burning. Some progress toward estimation of demand curves can be made through research into these costs.

The cost of production approach would cover total costs to society rather than to the individual alone for determining optimum demand for waste services functions. The costs added to individual costs would include those of littering and on-site burning. The point can be made that even if greater experience in the application of marginal cost pricing, and data from these applications, were available, it would still be necessary to modify demand curves so generated by social cost considerations for determining net social gains from marginal cost pricing.

Creation of More Experiments

Actual pricing experiments would still be necessary. Some costs, such as the bother costs of returnable bottles, and of carrying wastes to the curb, would be difficult to estimate in the absence of such experiments. Indeed, the research strategem most needed for investigation of economic approaches to solid waste collection/disposal services is the creation of more pricing experiments and the generation of demand side information from more experiments. The depth of the concerns over the costs of increasing waste volumes and evidence to date on potential gains from marginal cost pricing appear to justify this strategem.

Two Basic Approaches to the Creation of More Experiments

Two basic approaches are possible for the creation of more experiments and generation of more experimental data. One is the creation of a few well designed controlled experiments, with certain control areas remaining on flat charges for cross section comparison. Time series analysis would also be possible if historical information were available on quantities collected by subareas. The advantages of this approach lie in the care that can be applied for obtaining needed and reliable comparative results. A second approach is the promotion of more widespread adoption of pricing of solid waste collection/disposal service. In this case, cross section comparison of results with communities not adopting pricing would be used. Multiple regression techniques would be used to control for other variables. Again, time series analysis would also be possible given appropriate historical information. The advantages of this approach lie in the fact that greater variation in other variables can be considered with a greater output of data to cover various conditions for the same budget and time constraints.

A LIST OF RESEARCH QUESTIONS TO ASK IN SOLID WASTE SERVICES PRICING EXPERIMENTS

The focus of solid waste services pricing experiments should be on ultimate applicability, providing answers to solid waste systems managers' questions. Their questions would include what form financing should take, what specific charges should be set and how the level should be determined, and how to measure the services provided. They would also include what services to provide, and what degree of environmental amenities, such as litter control and clean up, to provide. As a research approach, it is useful to consider the various questions that might be asked. The following outline of possible question is offered:

1. What collection services and level of collection services should be provided?

    a. What frequency of service should be provided? Should this be decided on a systemwide or individual collection area basis?

    b. Should curb or back door service be provided? If back door, should it be optional, and if optional, should it be optional at each collection?

    c. Should unlimited-quantity service be provided, or should consideration be given to approaches that might limit or reduce quantities to be collected?

    d. Should combined, same frequency, and location of collection be offered for all residential solid wastes, or should separate collection be offered?

2. What degree of community cleanliness, in terms of freedom from litter and other pollution from solid wastes, is demanded, and how is this best achieved?

    a. What are the marginal benefits (what is the demand function for) different degrees of cleanliness?

    b. What are the various means for achieving cleanliness and what are the marginal cost functions (cost per unit of cleanliness achieved) of the various means?

    c. What is the optimum level of cleanliness and what are the optimum levels of input of the various means, given these demand and cost functions?

3. What disposal services and level of disposal services should be provided?

a. Should there be processing of wastes prior to ultimate disposal (e.g., incineration)?

(1) What are the benefits of processing in terms of reducing transportation, ultimate disposal, or other costs?

(2) What are the costs of processing, including economic costs (net of any energy values obtained) and environmental costs (air pollution)?

b. What are the options for ultimate disposal? If the least-cost alternative is by land disposal, what sanitary land-disposal standards should be set for this disposal?

(1) What are the marginal environmental benefits of added efforts to protect against environmental damages from the disposal operation? These might include benefits from:

(a) More frequent covering or burying of wastes.

(b) More careful site selection, for example, to find less permeable soils.

(c) More remote sites, for example, to remove the site further from population centers, or to remove further from groundwater sources.

(d) More care to separate off and neutralize the possible health and safety effects of potentially hazardous wastes that might be introduced into residential solid wastes.

(2) What are the marginal costs associated with achieving the marginal benefits?

4. How should collection/disposal services be financed?

a. What are the alternative ways of financing collection/disposal services? These may include:

(1) Flat charges, based on average costs of services actually rendered over a period of time.

(2) Incremental user charges, based on the incremental costs of the various collection/disposal services rendered.

(3) Strictly marginal cost pricing, which may be some combination of flat and incremental charges.

b. What are the advantages/disadvantages (benefits-costs) of alternative financing methods compared to existing financing methods, for example incremental compared to flat charge methods?

(1) What are the estimated changes in the amounts of the various services in shifting to incremental user charges?

(2) What are the direct benefits (estimated direct cost savings) from reducing these amounts?

(3) What are the direct costs to households (estimated loss in benefits) from reducing these amounts?

(4) What are the indirect costs from shifting to incremental charges?

(a) What are the added (or reduced) costs of administering such charges?

(b) What are the added environmental cleanliness costs?

(c) What are the tax/revenue sharing costs?

5. How can service requirements be best projected for planning and decision purposes?

a. What are the various projection methodologies and how would they be implemented?

b. Which projection methodologies are the more reliable in terms of accuracy? Which in terms of greater flexibility for different conditions or different modes of operation?

c. Which projection methodology, or methodologies, should be used for the particular system? If more than one, could there be irreconcilable differences in results, and how would this be handled?

6. What specific-system research is needed to make all of the above determinations?

a. What are the specific questions to be asked and answered?

b. What are the research procedures?

c. What are the data needs?

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APPENDIX A

AGENDA

	TUESDAY, SEPTEMBER 19, 1978	WEDNESDAY, SEPTEMBER 20, 1978
8:30-9:00	WELCOME: Robert J. Anderson KEYNOTE ADDRESS: Haynes Goddard	ADMINISTRATIVE COSTS OF USER FEES Barbara Stevens
9:00-9:30	EFFICIENCY OF USER CHARGES William Lanen	COMPARISONS OF ALTERNATIVE SOLID WASTE MANAGEMENT POLICIES Allen Miedema
9:30-10:00	EVALUATING THE EFFICIENCY OF THE SOLID WASTE CHARGE Steve Buchanan	TAX POLICY AND SECONDARY MATERIAL USE Robert C. Anderson
10:00-10:20	BREAK	BREAK
10:20-10:50	EQUITY CONSIDERATIONS IN USER CHARGES Roger Bolton	DISCUSSION Frank Smith Seymour Fiekowsky
10:50-11:20	OPTIONAL POLICY MIX James Hudson	SUMMARY GENERAL DISCUSSION: PRICING AND SOLID WASTE MANAGEMENT: FACT, FAITH, AND FICTION
11:20-12:00	DISCUSSION Robert C. Anderson Peter Kemper Haynes Goddard	
12:00-1:30	LUNCH	LUNCH
1:30-2:00	THE SEATTLE EXPERIMENT Bernard Booms	RESEARCH PROGRAMS AT EPA Oscar Albrecht
2:00-2:30	EXPERIENCE IN EUROPE W. David Conn	RESEARCH STRATEGIES Steve Hastings
2:30-3:00	ESTIMATES OF SECONDARY MATERIALS SUPPLY Taylor Bingham	WHAT THE SOLID WASTE MANAGER NEEDS Jack Dunn
3:00-3:20	BREAK	SUMMARY GENERAL DISCUSSION: RESEARCH PRIORITIES
3:20-3:50	PRICING MUNICIPAL REFUSE SERVICE Kenneth Wertz	
3:50-4:30	DISCUSSION John Thompson Jochen Kuhner Merrilee Bonney Seymour Fiekowsky	
7:20-8:30	ADDRESS BY: David Tunderman, CEQ	

APPENDIX B

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